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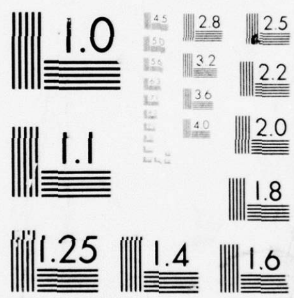
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Estimation of UG3RD Costs

January 1977
FINAL REPORT

DEPARTMENT OF TRANSPORTATION
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16. Abstract
The study estimates the additional costs that would be incurred by both the FAA and airport and airway users as a result of implementation of the Upgraded Third Generation Air Traffic Control System (UG3RD). Annual cost estimates are provided for engineering and development, facility and equipment expenditures, and maintenance expenses for the period 1976 through 2000. Separate cost detail is provided for the Discrete Address Beacon System, Intermittent Position Control, Control Automation, and the Wake Vortex Avoidance System. These components, in various combinations, have been evaluated as part of a cost-benefit analysis of the UG3RD system. In addition, certain unit costs were estimated for use in valuing potential UG3RD benefits. These costs consisted of the value of passenger time, aircraft operating costs, and the costs of aviation accidents and fatalities.

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This report summarizes research undertaken for the Federal Aviation Administration (FAA) by the Transportation System Center (TSC) and documented in TSC Report No. WP-420-C4-17 [35]. TSC staff efforts were directed by Dr. Robert Reck. Research described in the present document was started in April 1975 under PPA FA-638 and is concerned with estimation of capital and operating costs for the Upgraded Third Generation Air Traffic Control System (UG3RD). These estimates were incorporated in Policy Analysis of the UG3RD ATC System [18]. While costs presented in this paper are the best estimates of people familiar with individual systems elements, it is likely that the estimates will change with time and as designs for individual components are refined.

EXECUTIVE SUMMARY

The present study provides estimates of the additional costs that would be incurred by both the FAA and airport and airway users as a result of implementation of the Upgraded Third Generation Air Traffic Control System (UG3RD). Annual cost estimates are provided for engineering and development, facility and equipment expenditures, and maintenance expenses for the period 1976 through 2000. Separate cost detail is provided for the Discrete Address Beacon System, Intermittent Position Control, Control Automation, and the Wake Vortex Avoidance System. These components, in various combinations, have been evaluated as part of a cost-benefit analysis of the UG3RD system [ ]. In addition, certain unit costs were estimated for use in valuing potential UG3RD benefits. These costs consisted of the value of passenger time aircraft operating costs, and the costs of aviation accidents and fatalities.

Cost estimates represent marginal costs. Annual FAA engineering and development costs were obtained from various engineering development groups within the Federal Aviation Administration, from concurrent analyses of individual UG3RD components, and existing implementation plans. To determine FAA and user costs for facilities, equipment, and maintenance, annual inventory estimates of items, or net new additions, were multiplied by appropriate unit cost estimates.

Where ever possible, results of existing or concurrent studies of UG3RD components were used to provide, support, or validate the cost results presented here.

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1.0 Introduction

A system cost-benefit study of proposed investment in the Upgraded Third Generation Air Traffic Control (UG3RD) has been conducted by the Federal Aviation Administration (FAA) with the assistance of several independent research organizations. Findings are documented in Policy Analysis of the UG3RD ATC System [18].

Costs and benefits of implementing alternative UG3RD systems are estimated vis-a-vis continuation of the present air traffic control system. The analysis valued the costs and benefits of five alternative UG3RD systems composed of potential combinations of UG3RD components. Alternative UG3RD configurations selected for evaluation consisted of component combinations which produce system interaction and bound the range of potential program costs and types of benefits. For each alternative UG3RD configuration, the added cost of airport and airway services associated with UG3RD implementation was quantified for both the Federal Aviation Administration and for airway system users. Costs were compared with the value of potential improvements in the airport and airway system. Benefits consisted of increased airport capacity and reduced delay, savings from reduced FAA staff requirements, and improved airway system safety.

System cost-benefit findings are based on analyses supplied by several research organizations. MITRE Corporation evaluated the impact of various potential UG3RD configurations on airport capacity and aviation safety [32 & 33]. Battelle Columbus Laboratories translated UG3RD impacts on airport capacity into estimates of changes in aircraft and passenger delay [30]. Labor productivity impacts are based on research conducted at Stanford Research Institute [10] and Administrative Science Corporation [1]. Cost estimates and assessment of energy and environments impact of the UG3RD was the responsibility of the Transportation Systems Center (TSC).

The present document presents UG3RD cost estimates and describes estimation procedures.

1.1 Objective of the Study

The objective of the present study was to provide estimates of the additional costs that would be incurred by both the FAA and airport and airway users as a result of the implementation of a UG3RD system. Annual cost estimates are required for the period of envisioned system life, 1976 through 2000, and consist of engineering and development costs, facility and equipment expenditures, and operational maintenance expenses. The nine potential components of the UG3RD system are:

1. Discrete Address Beacon System (DABS)
2. Intermittent Positive Control (IPC)
3. Control Automation
4. Microwave Landing System (MLS)
5. Area Navigation (RNAV)
6. Aeronautical Oceanic Satellites (AEROSAT)
7. Airport Surface Traffic Control (ASTC)
8. Wake Vortex Avoidance System (WVAS)
9. Flight Service Station (FSS)

In addition to provision of UG3RD system cost estimates, certain unit costs were required in conjunction with estimation of potential UG3RD benefits. Thus, estimates were also prepared of aircraft operating costs by terminal, the value of passenger time, and costs of aviation accidents and fatalities.

1.2 Approach

A consistent set of annual system cost estimates were developed for four of the nine component programs of the UG3RD--WVAS, DABS, IPC, and control automation. Cost estimates of UG3RD components represent marginal costs, that is those costs that are exclusively associated with the implementation of the UG3RD program. Annual FAA engineering and development cost estimates were obtained from various engineering development groups within the FAA, from concurrent cost-benefit analysis of individual components1/ and from present FAA implementation and development plans (see UG3RD Baseline and Implementation Scenario [22]). Unit costs for FAA individual facilities and FAA and user equipment were also obtained from FAA development groups and individual component cost-benefit analyses, but this information was supplemented with data taken from independent research sources. To determine annual FAA and user costs for facilities, equipment, and maintenance, annual inventory estimates of those items, or net new additions, were multiplied by appropriate unit cost estimates. Data on net new additions and annual equipment inventories were taken from siting assumptions of the UG3RD cost-benefit analysis [18] and from other FAA implementation plans [22].

In addition to a system cost-benefit of the UG3RD, the FAA is also conducting cost-benefit studies of individual UG3RD components. Wherever possible, results of these studies of individual components were used to provide, support or validate the cost results used here. This promotes consistency between the present effort and other related cost research. Also, the present work has been formatted and incorporated into the UG3RD system cost-benefit analysis in a fashion that permits convenient updating of cost information.

1.3 Organization of the Report

The remainder of this report is organized to present the major assumptions that guided the study in Chapter 2. Cost analyses of UG3RD components are presented in Chapters 3 through 5. Unit cost data used in estimating certain potential cost savings obtainable through implementation of the UG3RD are contained in Chapter 6.

1/ Cost-benefit analyses of individual components of the UG3RD were conducted concurrently with the system cost-benefit analysis.

2.0 Major Assumptions

This Chapter details the major assumptions that affect the estimation of system-level costs in connection with the Upgraded Third Generation System Cost-Benefit Analysis. It details the configurations selected, the aviation scenarios pertinent to the cost estimation process, and discusses implementation and transition scenarios. Specific attention is given to the user fleet and avionics assumptions.

2.1 System Configurations

As indicated in Chapter 1, there are nine potential components which could be used to develop a UG3RD system (descriptions of these components are given in succeeding chapters of this report). With nine components from which to form combinations, there are numerous possible alternative UG3RD configurations. In conducting the UG3RD system cost-benefit analysis [18], a decision was therefore made to select a limited number of configurations for analysis. Candidates for inclusion in the system cost-benefit analysis were evaluated from several perspectives. First, configurations should provide benefits which are truely the products of an integrated system rather than simple aggregations of improvements obtainable from independent implementation of components. The combinations finally selected focused on benefits in the areas of capacity improvement, delay reduction, controller staff savings, safety improvements and energy and environmental impacts. A second criteria used to establish alternative configurations for the UG3RD system cost-benefit analysis was that the configurations should bound the range of possible system costs. Further, all systems had to be technically feasible and should indicate the sensitivity of UG3RD costs and benefits to the scope of program implementation.

Using these guides, the alternatives were distilled into five 1/ technically feasible UG3RD equipment configurations. The configurations studied in the UG3RD system cost-benefit analysis are presented in Table 2.1. Certain potential UG3RD components were excluded from these configurations because benefits obtainable from the components did not vary as a function of other elements included in the system. Excluded elements consisted

1/ Initially, a sixth configuration was considered, but it was discarded during the actual system cost-benefit analysis due to lack of significant difference in impacts of the configuration on airport capacity and delay.

TABLE 2.1
ALTERNATIVE UG3RD SYSTEM CONFIGURATIONS
EVALUATED BY SYSTEM COST BENEFIT ANALYSIS

Configuration Number	Component Composition	Siting Assumptions	Remarks on Selection
1	WVAS – Manual Automation – Basic Metering & Spacing, Data Distribution	Top 30 air carrier terminals All enroute centers	Most basic synergistic system with potential benefits of increased airport and airway capacity and some increase in controller productivity.
2	WVAS – Automated Automation – Advanced metering & spacing, data distribution, conflict resolution, control messages DABS	Top 30 air carrier terminals All enroute centers DABS at 100 sites	System embodies the highest envisioned level of airport and airway capacity improvement, major increases in controller productivity, and possible safety effects.
3	WVAS – Automated Automation – Advanced metering & spacing, data distribution, conflict resolution, control messages DABS	Top 30 air carrier terminals All enroute centers DABS at 300 sites	Same as configuration 2 except wider DABS coverage is provided
4	WVAS – Automated Automation – Advanced metering & spacing, data distribution, conflict resolution, control messages DABS, IPC	Top 30 air carrier terminals All enroute centers DABS & IPC at 100 sites	System embodies the highest envisioned level of airport and airway capacity improvement, increases in controller productivity and significant collision avoidance benefits.
5	WVAS – Automated Automation – Advanced metering & spacing, data distribution, conflict resolution, control messages DABS, IPC	Top 30 air carrier terminals All enroute centers DABS & IPC at 300 sites	Same as configuration 5 except wider DABS/IPC average is provided.

of the microwave landing system, flight service stations, area navigation, airport surface traffic control, and aeronautical ocean satellites. The costs and benefits of systems containing these items can be estimated by adding costs and benefits associated with the individual items to those of the systems listed in Table 2.1.

2.2 Future Aviation Scenarios

In responding to the Department of Transportation's review of the Upgraded Third Generation System, the Federal Aviation Administration produced a series of projections of future aviation activity. These forecasts are documented in UG3RD Baseline and Implementation Scenario [22] and are based on extensions of past trends in both aviation and the economy. They include the following types of data for the 1975-2000 time frame:

1. National Forecasts for the Period 1975 through 2000--annual operations, enplanements, and revenue passenger miles.

2. Characteristics of User Operations--fleet mixes and operational characteristics, airlines environments, and avionics capabilities, cost, and distribution.

3. Airports--inventory, status, and shifts in functional roles.

4. Regulatory and Economic Considerations--rate and route structure, cost allocation features, taxes, quotas, and curfews.

5. Limiting System Factors--energy, airspace, access, and materials limitations.

6. Implementation Considerations--inventory and costs by year.

For the purposes of this study, several additional elements of the future were considered important. Of special interest in estimating costs are assumptions about avionics equipage by year. It therefore became necessary to validate previous plans in these areas or update past information with more current or reasonable projections.

The recent Department of Transportation Study on the Advanced Air Traffic Management System (AATMS) provided a starting point in these two areas [34]. Results and methodology of the present cost study incorporated that work when other, more up-to-date information was not available. In the avionics area, AATMS Study defined six aircraft avionics classes as representative of the range of user equipment and capabilities that exist in the system. These classes are also used here. The AATMS Study populations and equipage for various aircraft avionics classes were updated, however, to be consistent with total fleet size projections given in UG3RD Baseline and Implementation Scenario. In general, avionics implementation timing was based on projected initial equipment availability by year, final operational configuration by year (see Table 2.4), and an assumed linear growth rate between those points. Specific procedures for each UG3RD component are given in Chapter 3. The following parts of this chapter discuss fleet size and avionics equipment by class for the fleet.

2.3 Fleet Size Forecasts

Forecasts of the total air carrier and general aviation fleets between the years 1975 and 2000 used in this Study were developed for 5-year intervals by the Office of Aviation Policy [22]. These statistics are included in Table 2.2 and consist of total fleet population estimates for air carriers and several different categories of general aviation aircraft--single engine, multi-engine, turbine, and other. Linear interpolation was used to estimate fleet populations for the intermediate years in Table 2.2. Military aircraft were assumed to be constant between 1976 and the year 2000. Total fleet size estimates subsequently were used to develop aircraft avionics class populations used in the present study.

2.4 Aircraft Avionics Classes

The Advanced Air Traffic Management System Study defined six aircraft avionics classes to represent the range of 1995 requirements and needs for flight services [34]. These classes represent levels of capability and, in total, the diversity of avionics complements that the future fleet may be expected to install and use. Table 2.3 defines these user classes. It is expected that different users would carry avionics of different quality, redundancy, and degree of sophistication, based on the cost, safety, and level of service they choose, and the airspace category in which they wish to fly. Typical avionics complement for each aircraft avionics class assuming implementation of all potential UG3RD components is given in Table 2.4

TABLE 2.2

AIRCRAFT FLEET PROJECTIONS

					G.A. Fleet Breakdown			
Year	G.A. Fleet	Air Carrier Fleet	Military Fleet	Total Fleet	Single Engine	Multi Engine	Turbine	Other
1975	161500.	2526.	20000.	184026.	131687.	20123.	4005.	5685.
1976	167000.	2609.	20000.	189609.	135444.	21172.	4482.	5902.
1977	172000.	2687.	20000.	194687.	138749.	22181.	4967.	6103.
1978	178000.	2762.	20000.	200762.	142813.	23343.	5504.	6340.
1979	184000.	2838.	20000.	206838.	146825.	24531.	6065.	6580.
1980	189000.	2907.	20000.	211907.	149990.	25610.	6615.	6785.
1981	195000.	2975.	20000.	217975.	154128.	26762.	7102.	7008.
1982	202000.	3095.	20000.	225095.	159014.	28074.	7644.	7268.
1983	212100.	3185.	20000.	235285.	166286.	29847.	8327.	7640.
1984	222700.	3259.	20000.	245959.	173884.	31726.	9059.	8031.
1985	233800.	3333.	20000.	257103.	181803.	33714.	9843.	8440.
1986	245000.	3407.	20000.	268407.	189728.	35755.	10658.	8859.
1987	256000.	3456.	20000.	279456.	197427.	37806.	11494.	9272.
1988	268500.	3530.	20000.	292030.	206208.	40119.	12432.	9741.
1989	281700.	3654.	20000.	305354.	215444.	42582.	13437.	10237.
1990	294300.	3753.	20000.	318053.	224139.	44998.	14450.	10713.
1991	328100.	3851.	20000.	331951.	233663.	47645.	15565.	11227.
1992	322600.	3950.	20000.	346550.	243628.	50448.	16756.	11768.
1993	337800.	4024.	20000.	361824.	254026.	53413.	18025.	12336.
1994	353600.	4123.	20000.	377723.	264776.	56526.	19370.	12928.
1995	370300.	4197.	20000.	394497.	276096.	59840.	20811.	13553.
1996	387600.	4296.	20000.	411896.	287961.	63198.	22222.	14218.
1997	405900.	4395.	20000.	430295.	300474.	66771.	23732.	14924.
1998	424600.	4469.	20000.	449069.	313185.	70462.	25306.	15647.
1999	444900.	4567.	20000.	469467.	326972.	74476.	27020.	16432.
2000	465800.	4641.	20000.	490441.	341090.	78650.	28817.	17242.
2001	487700.	4715.	20000.	512415.	355826.	83055.	30725.	18094.

TABLE 2.3

AIRCRAFT AVIONICS CLASSES

Class A:

- IFR capability in all controlled (mixed, positive control, and high density) airspace regions of the National Airspace System under instrument meteorological conditions (only VFR flights may be conducted in uncontrolled airspace).

- Equips with dual, high quality avionics characteristic of air carrier and military aircraft.

Class B:

- IFR capability in all mixed and positive controlled airspace regions (requiring 3D-RNAV), except where procedures requiring 4D-RNAV equipment are in effect.

- Equips with dual, high quality avionics characteristic of expensive general aviation aircraft.

Class C:

- Typically operates IFR in mixed airspace regions.

- Has nonredundant, medium quality avionics of limited navigation (as above 2D-RNAV) and data link communication capability.

Class D:

- Generally operates VFR in all low-density terminals and mixed on-route airspace.

- Has low cost avionics without area navigation equipment.

Class E:

- Typically operates VFR in mixed or uncontrolled airspace.

- Has low cost avionics with VOR navigation equipment.

Class F:

- Operates in uncontrolled airspace with only voice communications and minimum VOR navigation capabilities.

TABLE 2.4

TYPICAL AVIONICS COMPLEMENTS BY AIRCRAFT AVIONICS CLASS ASSUMING IMPLEMENTATION OF ALL POSSIBLE UG3RD COMPONENTS

Class	Avionics
A	Dual High Quality DABS Transponders Dual High Quality Encoding Altimeters Dual High Quality IPC/ATC Data Link Logic and Displays Dual 4D-RNAV Navigation Equipment Dual High-Quality Microwave Landing System Equipment Dual AEROSAT Avionics (Optional) Dual Voice Communications Equipment
B	Dual High Quality DABS Transponders Dual High Quality Encoding Altimeters Dual IPC/ATC Logic and Displays Dual Voice Communication Dual 3D-RNAV Navigation Equipment Dual Microwave Landing System Equipment Dual AEROSAT Avionics (Optional)
C	DABS Transponder Encoding Altimeter IPC/ATC Logic and Displays 2D-RNAV Navigation Equipment Microwave Landing System Equipment Dual VOR Navigation Equipment Dual Voice Communications Equipment
D	DABS Transponder Encoding Altimeter IPC Logic and Displays Dual VOR Navigation Receivers Dual Voice Communications Equipment
E	DABS Transponder Encoding Altimeter IPC Logic and Display Voice Communications Equipment VOR Navigation Receiver
F	Voice Communications Equipment VOR Navigation Receiver

Users are classified as "cooperative" when they carry the minimum required equipment to enable them to fly in mixed airspace, namely a surveillance transponder, data link (IPC) logic and displays when appropriate, a voice communication transceiver, and some type of navigation equipment. Users can choose to install duplicate sets of equipment to increase reliability. Optional collision avoidance or proximity warning system equipment may also be added. It is anticipated that a wide variety of avionics subsystems will be available, enabling users to assemble a functional complement of equipment with considerable cost latitude.

2.5 Estimates of Aircraft Avionics Population Size

The aircraft data presented in Table 2.2 is classified by user type, and within user type by type of aircraft-- air carrier, military, and general aviation-single-engine, multi-engine, turbine, and other. To estimate avionics cost, the present study translated the FAA fleet forecast data into a year-by-year forecast according to the aircraft avionics classes defined in Table 2.3. The methodology for translating FAA forecast data into the six aircraft avionics classes follows.

Class A users were assumed to be comprised of all air carrier and air taxi aircraft, as well as half of the military fleet. Class B aircraft were assumed to include all general aviation turbine aircraft, 80 percent of general aviation multi-engine aircraft, and those military aircraft excluded from Class A. Remaining general aviation multi-engine aircraft, general aviation "other" aircraft, and 25 percent of the general aviation single-engine fleet were grouped into Class C.

Class E consists of 25 percent of the general aviation single-engine aircraft and Class F consists of 10 percent of the general aviation fleet, taken from the classification of single-engine aircraft. The remainder of the fleet, which consists of the remainder of the general aviation single-engine fleet, was defined as Class D.

Using the above methodology, fleet population estimates made by the Federal Aviation Administration were translated into relevant estimates of fleet size by avionics categories. Table 2.5 presents a year-by-year breakdown of class populations. These are consistent with the forecast data presented in Table 2.2.

TABLE 2.5

AIRCRAFT AVIONIC CLASS POPULATION PROJECTIONS

Year	Class A	Class B	Class C	Class D	Class E	Class F	Total Fleet
1975	12526.	31110.	41625.	49694.	32922.	16150.	184026.
1976	12609.	32479.	42939.	51022.	33861.	16700.	189609.
1977	12687.	33821.	44117.	52174.	34687.	17200.	194687.
1978	12762.	35345.	45545.	53606.	35703.	17800.	200762.
1979	12838.	36916.	46966.	55012.	36706.	18400.	206838.
1980	12907.	38383.	48124.	56095.	37498.	18900.	211907.
1981	12975.	39849.	49555.	57564.	38532.	19500.	217975.
1982	13095.	41507.	51233.	59307.	39754.	20200.	225095.
1983	13185.	43697.	53688.	61933.	41572.	21210.	235285.
1984	13259.	46026.	56260.	64672.	43471.	22270.	245959.
1985	13333.	48500.	58948.	67521.	45451.	23380.	257133.
1986	13407.	51050.	61654.	70364.	47432.	24500.	268407.
1987	13456.	53630.	64300.	73114.	49357.	25600.	279456.
1988	13530.	56533.	67311.	76254.	51552.	26850.	292030.
1989	13654.	59632.	70485.	79552.	53861.	28170.	305354.
1990	13753.	62699.	73497.	82639.	56035.	29430.	318053.
1991	13851.	66063.	76790.	86022.	58416.	30810.	331951.
1992	13950.	69637.	80243.	89554.	62907.	32260.	346550.
1993	14024.	73426.	83855.	93233.	63506.	33780.	361824.
1994	14123.	77418.	87601.	97028.	66194.	35360.	377723.
1995	14197.	81675.	91553.	101018.	69024.	37030.	394497.
1996	14296.	85941.	95688.	105220.	71990.	38760.	411896.
1997	14395.	91487.	100058.	108647.	75119.	40590.	430295.
1998	14469.	95199.	104512.	114132.	78296.	42460.	449069.
1999	14567.	100325.	109346.	118996.	81743.	44490.	469467.
2000	14641.	105670.	114312.	123965.	85272.	46580.	490441.
2001	14715.	111322.	119508.	129143.	88956.	48770.	512415.

Five avionics complexes are required to interface with the Upgraded Third Generation System. These five subsystems are the Discrete Address Beacon System (DABS), Intermittent Positive Control (IPC), Microwave Landing System (MLS), Area Navigation (RNAV), and Aeronautical Oceanic Satellite (AEROSAT) Avionics. These five equipment complexes have varying implications insofar as the total system cost are concerned. The extent of equipage for DABS and IPC will change with the system configuration under analysis. Equipage of other avionics equipments are constants for the all configurations evaluated by the UG3RD system cost-benefit analysis. Subsequent chapters discuss assumptions for each of these components as a function of the UG3RD system configuration, year, and aircraft avionics classes. Equipment indicated in Table 2.4 which are not part of the UG3RD were not costed as a part of this project. Complete system cost estimates for these elements are available in the various reports of the AATMS Study.

3.0 Discrete Address Beacon System (DABS) and Intermittent Positive Control (IPC)

The Discrete Address Beacon System (DABS) is an aircraft surveillance system which will provide a data link between ground stations and controlled aircraft. The data link feature will be capable of supporting an automated Intermittent Positive Control System (IPC). DABS is an evolutionary replacement for the present surveillance system--the Air Traffic Control Radar Beacon System (ATCRBS).

Cost analyses of DABS and IPC assume that at the time of transition from ATCRBS to DABS or DABS and IPC in combination, the ATCRBS system will be at a certain stage of development. The relevant costs of DABS or DABS and IPC implementation for purposes of cost-benefit analysis are the difference between total expenses of design, purchase, and maintenance of DABS and IPC equipment and the cost of continuing to expand, improve, and use ATCRBS in the absence of DABS and IPC introduction. Thus, this chapter first presents estimates of annual expenses that will be incurred in continuing to use the ATCRBS system. Second, estimates of the annual cost of designing, purchasing, and maintaining various configurations of DABS and IPC equipment are given. Finally, differentials of DABS and IPC costs vis-a-vis continuation of the ATCRBS surveillance system are provided.

3.1 Baseline--Continuation of ATCRBS

The ATCRBS is a radar beacon system where a ground interrogator transmits a pair of time-coded pulses to aircraft by a highly directive antenna which in turn elicits a reply from airborne transmitters. The 15-bit identity or altitude message from responding aircraft is radiated nondirectionally. The system is used in conjunction with primary radar. Present airport and airway system plans call for retention of the existing 131 enroute facilities and expansion of terminal facilities from 180 to 227 [24] by 2000. Since 1961, performance of the ATCRBS system has been gradually upgraded and it has become the primary source of surveillance for air traffic control. The original 64-code reply message has been upgraded to 4096-code capability. Frequently encountered problems at the introduction of ATCRBS, for example, the phenomena of false targets or ring around on controller's displays, have been reduced.

It is anticipated that certain improvements will be made to the present ATCRBS system independent of any decision to implement DABS and IPC [27]. These improvements consist of the following items.

1. Antenna System - aperture and monopulse

2. Multichannel Receiver

3. ATCRBS Reply Processor

4. Surveillance Processor

5. ATCRBS Reply Correlator

6. ATCRBS Scan-to-Scan Correlator

7. Radar/Beacon Correlator, and

8. Surveillance Data Distribution Interface

Presently anticipated ATCRBS improvements include the monopulse receiver which will improve azimuth accuracy. In addition, the monopulse receiver will detect a target on a single pulse which will reduce electromagnetic interference on radar screens. Range accuracy of ATCRBS will remain the same as present experience because this source of error lies in transponder characteristics and will not be altered until DABS transponders become available. Similarly, asynchronous garble and false targets which will continue to exist under ATCRBS will be eliminated by DABS.

The per unit facility and equipment (F&E) costs of an ATCRBS ground site was $258,000 in 1972 [25]. Annual operations and maintenance costs in 1972, averaged over the 313 sites, are estimated at $22,000. Additional F&E unit costs per site for anticipated ATCRBS improvements were estimated at $180,000 [21] and annual operations and maintenance costs are estimated at $18,000 per year per site, or 10 percent of the F&E cost. Total unit costs of new ATCRBS facilities, including all proposed improvements, in 1975 dollars, are: $502,000 for facility and equipment, and $45,000 annual maintenance cost.

General aviation ATCRBS transponders are currently available for about $600. Air carrier avionics cost about $13,775; Mode C equipment costs about $6,000. Additional information on baseline avionics costs are given in Table 3.1. An estimate of aircraft which were equipped in 1975 with beacon equipment is shown in Table 3.2. Even though the military fleet were known to be only half equipped with Mode C equipment in 1975, they have an aggressive program to complete the Mode C equipage of their fleet. All military aircraft are, therefore, assumed to be Mode C equipped today. Estimates of general aviation transponder and Mode C equipment vary.

TABLE 3.1

ATCRBS AVIONICS

Aircraft Avionics Class	Transponder	Mode C Altimeter
A (Commercial, Dual)	$13,775	$6,000
(Military)	3,850	1,500
B (General Aviation, Dual)	11,160	6,000
(Military)	3,850	1,500
C (General Aviation)	2,200	1,680
D (General Aviation)	700	720
E (General Aviation)	700	720

TABLE 3.2

1975 FLEET EQUIPMENT:

BASELINE BEACON AVIONICS

User Category	Number of Aircraft	Transponder Equipped	Mode C Altimeter Equipped
Air Carrier	2,300	2,300	1,900
Military	20,000	20,000	10,000
General Aviation	133,000	64,000	10,000

Tables 3.3 and 3.4 present estimates of the percent of aircraft avionics classes equipped with ATCRBS transponders and Mode C equipment for the period 1975 through 2000. Table 3.3 reflects past trends to more equipment spurred by greater emphasis on Terminal Control Areas, general lowering of the positive controlled air space floor, improved radar services available, and upward growth in Mode C equipment based on many of the same factors. The aircraft avionics classes are those discussed in Chapter 2.

Tables 3.3 and 3.4 were used as the basis for preparing a baseline scenario of ATCRBS avionics deployment and total user costs by year (see Table 3.5). Based on Tables 3.3 and 3.4, the additional number of ATCRBS transponders and Mode C equipment added to the fleet each year were computed. Net additions were multiplied by unit cost estimates for each aircraft avionics class to estimate the total annual avionics F&E cost for the implementation of baseline beacon and Mode C equipment and presents net new avionics purchase costs that will be borne by users. In addition, while the cost of existing ATCRBS and Mode C equipment is not in Table 3.5, the cost of replacing these items in the future (replacement avionics purchases) is estimated and included in the grand total of avionics purchases. Table 3.6 summarizes all anticipated additional costs--both user avionics costs and costs borne by the FAA for facility expansion and improvements--of continuing with ATCRBS through the year 2000. The table was used as the baseline avionics equipment scenario in determining the additional cost of DABS or DABS/IPS configurations.

TABLE 3.3

PERCENT OF AIRCRAFT WITH ATCRBS TRANSPONDER

Aircraft Avionics Class	Year					
	1975	1980	1985	1990	1995	2000
A	100	100	100	100	100	100
B	100	100	100	100	100	100
C	60	70	80	90	100	100
D	25	35	45	55	65	75
E	25	30	35	40	45	50
F	0	0	0	0	0	0

TABLE 3.4

PERCENT OF AIRCRAFT WITH MODE C ALTIMETER

Aircraft Avionics Class	Year					
	1975	1980	1985	1990	1995	2000
A	100	100	100	100	100	100
B	100	100	100	100	100	100
C	15	30	45	50	50	50
D	15	30	45	50	50	50
E	15	15	15	15	15	15
F	0	0	0	0	0	0

TABLE 3.5

BASELINE ATCRBS AVIONICS COSTS
(Millions 1975 Dollars)

Year	AIRCRAFT AVIONICS CLASS CLASS A			AIRCRAFT AVIONICS CLASS CLASS B			AIRCRAFT AVIONICS CLASS CLASS C				
	Total Class A Fleet on January 1	New Aircraft Added/Yr.	Value of Avionics Added	Total Class B Fleet on January 1	New Aircraft Added/Yr.	Value of Avionics Added	Number of Transponders on January 1	Number of Transponders Added/Yr.	Number of Altimeters on January 1	Number of Altimeters Added/Yr.	Value of Avionics Added
1975	12,526	83	1.64	31,110	1,369	23.49	24,975	1,646	6,243	1,486	6.12
1976	12,609	78	1.54	32,479	1,342	23.03	26,622	1,613	7,729	1,535	6.13
1977	12,687	75	1.48	33,821	1,524	26.15	28,235	1,825	9,264	1,667	6.82
1978	12,762	76	1.54	35,345	1,571	26.96	30,060	1,877	10,931	1,750	7.07
1979	12,838	69	1.36	36,916	1,467	25.17	31,937	1,748	12,681	2,056	7.29
1980	12,907	68	1.34	38,383	1,466	25.16	33,685	1,995	14,437	1,916	7.61
1981	12,975	120	2.37	39,849	1,658	28.45	35,680	2,232	16,353	2,091	8.42
1982	13,095	90	1.78	41,577	2,190	37.58	37,912	2,891	18,444	2,494	10.55
1983	13,185	74	1.46	43,697	2,329	39.97	40,803	3,080	20,938	2,691	11.30
1984	13,259	74	1.46	46,026	2,474	42.45	43,883	3,275	23,629	2,398	12.08
1985	13,333	74	1.46	48,500	2,550	43.76	47,158	3,398	26,527	1,834	10.56
1986	13,407	49	.97	51,250	2,580	44.27	50,556	3,456	28,361	1,860	10.72
1987	13,456	74	1.46	53,630	2,903	49.82	54,012	3,875	30,221	2,088	12.04
1988	13,530	124	2.45	56,533	3,099	53.18	57,887	4,140	32,309	2,228	12.85
1989	13,654	99	1.96	59,632	3,067	52.63	62,027	4,120	34,537	2,211	12.79
1990	13,753	98	1.93	62,699	3,364	57.73	66,147	4,500	36,748	1,647	12.67
1991	13,851	99	1.96	66,063	3,514	61.33	70,647	4,781	38,395	1,727	13.42
1992	13,950	74	1.46	69,637	3,789	65.02	75,428	5,072	40,122	1,806	14.19
1993	14,024	99	1.96	73,426	3,992	68.50	80,500	5,349	41,928	1,872	14.91
1994	14,123	74	1.46	77,418	4,257	73.05	85,849	5,704	43,800	1,976	15.77
1995	14,197	99	1.96	81,675	4,266	73.20	91,553	4,135	45,776	2,068	12.57
1996	14,296	99	1.96	85,941	4,546	78.01	95,688	4,370	47,844	2,185	13.28
1997	14,395	74	1.46	90,487	4,712	80.86	100,058	4,454	50,029	2,227	13.54
1998	14,469	98	1.94	95,199	5,126	87.96	104,512	4,834	52,256	2,417	14.69
1999	14,567	74	1.46	100,321	5,345	91.72	109.346	4,966	54,673	2,483	15.20
2000	14,641	74	1.46	105,670	5,652	96.99	114,312	5,192	57,136	2,598	15.78
2001	14,715			111,322			119,508		59,754		

TABLE 3.5

BASELINE ATCRBS AVIONICS COSTS
(Millions 1975 Dollars)

Year	AIRCRAFT AVIONICS CLASS CLASS D					
	Total Fleet on January 1	Number of Transponders on January 1	Number of Transponders Added/Yr.	Number of Altimeters on January 1	Number of Altimeters Added/Yr.	Value of Avionics Added
1975	49,694	12,423	1,369	7,454	1,741	2.21
1976	51,082	13,792	1,338	9,195	1,761	2.21
1977	52,174	15,130	1,487	10,956	1,909	2.41
1978	53,606	16,617	1,530	12,865	1,988	2.50
1979	55,012	18,153	1,480	14,854	1,975	2.46
1980	56,095	19,633	1,666	16,828	2,168	3.23
1981	57,564	21,299	1,830	18,996	2,354	2.97
1982	59,307	23,129	2,263	21,350	2,803	2.59
1983	61,933	25,392	2,416	24,153	3,009	3.86
1984	64,642	27,808	2,576	27,162	3,222	4.12
1985	67,521	30,384	1,687	30,384	1,983	3.31
1986	70,364	33,071	2,454	32,367	1,976	3.37
1987	73,114	35,823	3,064	34,363	2,238	3.75
1988	76,254	38,889	3,273	36,601	2,379	4.00
1989	79,551	42,162	3,289	38,980	2,339	3.98
1990	82,639	45,451	3,581	41,319	1,692	3.73
1991	86,022	49,032	3,804	43,011	1,766	3.93
1992	89,554	52,836	4,036	44,777	1,839	4.15
1993	93,233	56,872	4,255	46,616	1,898	4.35
1994	97,078	61,127	4,534	48,514	1,995	4.61
1995	101,018	65,661	4,836	50,509	2,101	4.90
1996	105,220	70,497	5,159	52,610	2,313	5.28
1997	109,644	75,656	5,377	54,823	2,243	5.37
1998	114,132	81,033	5,834	57,066	2,432	5.83
1999	118,996	86,867	6,106	59,498	2,474	6.03
2000	123,965	92,97	3,884	61,922	2,589	4.58
2001	129,143	96,857		64,571		

TABLE 3.5

BASELINE ATCRBS AVIONICS COSTS
(Millions 1975 Dollars)

AIRCRAFT AVIONICS CLASS CLASS E								
Year	Total Fleet on January 1	Number of Beacons on January 1	Number of Beacons Added/Year	Number of Altimeters on January 1	Number of Altimeters Added/Yr.	Value of Avionics Added	Total Value of Avionics Added	Relevant Avionics Purchases
1975	32,922	8,230	573	4,938	141	.50	33.96	
1976	33,861	8,803	562	5,079	124	.48	33.39	
1977	34,687	9,365	631	5,203	152	.55	37.41	
1978	35,705	9,996	648	5,355	150	.56	28.63	
1979	36,706	10,644	605	5,505	120	.51	36.79	
1980	37,498	11,249	694	5,624	155	.60	37.94	
1981	38,532	11,944	777	5,779	184	.67	42.88	
1982	39,754	12,721	997	5,963	272	.90	53.40	
1983	41,572	13,718	1,062	6,235	285	.95	57.54	
1984	43,471	14,780	1,127	6,520	297	1.00	61.11	
1985	45,451	15,907	1,168	6,817	297	1.03	60.13	61.4
1986	47,432	17,075	1,187	7,114	289	1.04	60.37	64.8
1987	49,357	18,262	1,327	7,403	329	1.17	68.24	68.1
1988	51,552	19,589	1,416	7,732	347	1.24	73.92	71.9
1989	53,861	21,005	1,409	8,079	326	1.22	72.56	75.7
1990	56,635	22,414	1,536	8,405	357	1.34	77.40	79.4
1991	58,416	23,950	1,630	8,762	374	1.41	82.05	83.2
1992	60,907	25,580	1,727	9,136	389	1.49	86.31	87.5
1993	63,506	27,307	1,818	9,525	404	1.56	91.28	90.8
1994	66,194	29,125	1,935	9,929	424	1.66	96.54	98.5
1995	69,024	31,060	2,055	10,353	445	1.76	94.39	104.7
1996	71,990	33,115	2,190	10,798	469	3.27	101.80	110.7
1997	75,119	35,305	2,277	11,267	477	1.93	103.16	116.7
1998	78,296	37,582	2,472	11,744	517	2.10	112.52	123.6
1999	81,743	40,054	2,582	12,261	529	2.19	116.50	130.9
2000	85,272	42,636	1,842	12,790	553	1.69	120.50	138.7
2001	88,956	44,478		13,343				

TABLE 3.6

FUTURE COST OF ATCRBS
INCLUDING EXPANSION AND IMPROVEMENTS 1/
(Millions 1975 Dollars)

Cost Category / Year	Facilities and Equipment			Operations and Maintenance		
	New ATCRBS Sites	ATCRBS Improvements	Avionics Purchases 2/	ATCRBS Sites	ATCRBS Improvements	Avionics
1976	.6	-	33.3	8.5	-	64.8
1977	.6	6.8	37.4	8.6	-	68.1
1978	.6	6.8	38.6	8.6	.7	71.9
1979	1.0	6.8	36.7	8.7	1.4	75.7
1980	1.0	6.8	37.9	8.8	2.0	79.4
1981	1.0	6.8	42.9	8.9	2.7	83.2
1982	1.0	6.8	53.4	9.0	3.4	87.5
1983	1.0	6.8	57.5	9.0	4.1	92.8
1984	1.0	6.8	61.1	9.1	4.7	98.5
1985	1.0	6.8	121.5	9.2	5.4	104.7
1986	1.0	6.8	125.2	9.2	6.1	110.7
1987	.6	.4	140.1	9.4	6.1	116.7
1988	.6	.4	149.4	9.4	6.2	123.6
1989	.6	.4	148.3	9.5	6.2	130.9
1990	.6	.4	156.8	9.5	6.2	138.2
1991	.3	.2	165.3	9.6	6.3	145.9
1992	.3	.2	173.8	9.6	6.3	154.6
1993	.3	.2	184.1	9.6	6.3	162.8
1994	.3	.2	195.0	9.6	6.3	171.9
1995	.3	.2	199.1	9.7	6.3	191.0
1996	.3	.2	212.5	9.7	6.3	201.2
1997	.3	.2	219.9	9.7	6.4	211.5
1998	.3	.2	236.1	9.8	6.4	223.7
1999	.3	.2	247.4	9.8	6.4	234.4
2000	.3	.2	258.7	9.8	6.4	246.5
TOTAL	15.2	71.6	3,332.0	232.3	118.6	3,388.8

1/ Costs exclude engineering and development expenses for ATCRBS improvements. These are estimated at $100,000 per year for the period 1976 through 1983.

2/

3.2 DABS and IPC Implementation

The fundamental difference between DABS and ATCRBS is in the manner of addressing aircraft and selecting aircraft to respond to an interrogator. Under ATCRBS, all aircraft within antenna beam width are addressed with the same code. With DABS, each aircraft is assigned a unique address code, and each aircraft responds only to an interrogation that includes that address. Therefore, each DABS interrogation is directed at a particular aircraft. An integral part of DABS is a data link where messages may be added immediately following the discrete address, thus, providing a ground-air-ground digital communications capability.

Two major advantages accrue from the use of discrete addresses. An interrogator will be able to limit its interrogations to particular targets of interest, rather than continuously interrogate all targets within line-of-sight. Second, by appropriate timing of interrogations and channel management, aircraft responses will not overlap. As a result, two fundamental ATCRBS limitations will be overcome: system saturation and synchronous garble.

Another significant feature in DABS is that it can support a collision avoidance system utilizing ground-derived threat data and the DABS data link. Intermittent Position Control (IPC) is a ground based collision avoidance system using DABS surveillance and data link communications and computer tracking to provide automatic warning and maneuver commands to DABS/IPC equipped aircraft to avoid potential collision hazards with other beacon-equipped aircraft. The IPC utilizes DABS surveillance data to generate its own aircraft track and position predictions. From these, predictions of potential conflict situations are made and pilot warning and conflict resolution messages are sent to the aircraft involved utilizing the DABS data link.

3.2.1 Implementation Assumptions

The UG3RD system cost-benefit analysis evaluates alternative configurations which assume an absence of DABS and IPC (Configuration 1), installation of DABS with and without IPC at 100 sites (Configurations 2 and 4), and installation of DABS with and without IPC at 300 sites (Configurations 3 and 5). See Table 2.1 for siting and configuration assumptions.

3.2.1.1 FAA Facilities and Equipment

Table 3.7 summarizes the assumed implementation schedule for DABS and IPC sites. It was assumed that a final implementation decision of DABS and IPC equipment would be made in the early 1980's. The first deployment would take place in 1984. This assumption is consistent with an optimistic estimate of DABS and IPC technical availability made by MITRE Corporation and the Office of Systems Engineering Management (OSEM), FAA [26]. Each site was assumed to require two years for installation, checkout, and commissioning. Final completion of installations under all configurations is assumed to occur in 1992. Overall implementation rates are generally consistent with present implementation plans provided by the Office of Aviation System Plans, FAA, appearing in UG3RD Baseline and Implementation Scenario [22]. Table 3.7 is used to help determine cost streams associated with DABS and IPC implementation.

3.2.1.2 User Avionics

Estimates were also made of the acquisition of DABS and IPC avionics by the civil and military air fleets. Assuming that manufacturers initiate avionics production soon after a Government decision to implement DABS and/or IPC, avionics equipment would be available for purchase by 1985. User costs of DABS and IPC avionics depend not only on equipment prices, but also on the quality of equipment purchased by the user and the extent to which the fleet is outfitted. Given uncertainty about the future equippage level of the fleet and the quality of avionics which will be installed, a range estimate was established for the DABS/IPC component. The upper bound assumes a large portion of airline quality equipment will exist in the general aviation fleet; the lower bound assumes a predominance of standard and medium quality avionics.

Implementation levels and rates for DABS/IPC avionics are not considered to vary with the assumed quality of equipment purchased, but are assumed to vary with the extent to which DABS/IPC service is initiated by FAA. Accordingly, separate user avionics deployment assumptions are made for UG3RD Configurations 2 and 3, UG3RD Configuration 4, and UG3RD Configuration 5. Table 3.8 summarizes the deployment assumptions for the overall general aviation fleet. In general, the percent of equipped aircraft increases in future years and increases as the extent of FAA service increases. Detailed discussions of the assumed avionics deployment for individual UG3RD configurations are discussed in separate sections below.

TABLE 3.7

DABS AND IPC SITE IMPLEMENTATION SCHEDULES

UG3RD Configurations / Year	Configurations 2 and 4	Configurations 3 and 5
1984	10	15
1985	15	35
1986	25	50
1987	30	50
1988	20	50
1989	0	50
1990	0	50
TOTAL	150	300

TABLE 3.8

GENERAL AVIATION EQUIPAGE--2000
(Percent of Total G.A. Fleet)

Equipment Assumption:	Transponder and Mode C			Transponder Only			No Surveillance Avionics		
	Configurations			Configurations			Configurations		
Year	1,2,3	4	5	1,2,3	4	5	1,2,3	4	5
1975	15	15	15	25	25	25	60	60	60
1980	35	35	35	15	15	15	50	50	50
1985	45	45	45	10	10	10	45	45	45
1990	50	55	60	15	10	5	35	35	35
1995	50	65	85	20	5	0	30	30	15
2000	50	65	85	25	10	0	25	25	15

Configurations 1, 2, 3 = ATCRBS, DABS only

Configuration 4 = 100 DABS/IPC sites

Configuration 5 = 300 DABS/IPC sites

Avionics Deployment for Configurations 2 and 3. The number of DABS avionics units and compatible Mode C altimeters were estimated for Configurations 2 and 3, utilizing data given in Tables 3.3 and 3.4. It was assumed that there would be no additional incentive to users to equip with DABS avionics beyond that already projected for baseline ATCRBS equipment. DABS avionics acquisitions by aircraft avionics Classes A and B were assumed to occur during the 5-year period from 1985 to 1989, while users in Classes C, D, and E were assumed to phase over to DABS avionics during the time period between 1985 and 1994.

Table 3.9 presents the results of these assumptions in terms of the number of DABS avionics added to the fleet each year by aircraft avionics category. Unit costs for avionics and total acquisition costs are discussed in Section 3.2.2.

Avionics Deployment for Configurations 4 and 5. The deployment of avionics for Configurations 4 and 5 was considered to be significantly different from those cases where a DABS-only system and avionics were deployed. Tables 3.10 and 3.11 present the percent of users equipped with DABS transponder and Mode C altimeters for Configuration 4. Tables 3.12 and 3.13 present similar information for Configuration 5.

Classes A and B users were again assumed to equip completely with DABS/IPC avionics during the 1985 to 1989 interval because these classes will fly into the terminals where the greatest benefits for DABS and IPC stand to be gained. Historically, these user classes have promptly equipped with other ATC-related equipment. Aircraft avionics Classes C, D, and E were assumed to equip to their steady-state level between 1985 and 1994. Tables 3.10 and 3.12 reflect the assumptions made in this study as to what those ultimate implementation states will be. Configuration 4 shows an additional proclivity to beacon equipment beyond that anticipated in the baseline case because of the advantages, from a safety point of view, to be gained by carrying both DABS and IPC equipment. Configuration 5 projections embody a greater expectation because there would be more ground sites providing important safety-related services. Comparable assumptions on the implementation of Mode C equipment are also made. Tables 3.11 and 3.12 reflect

TABLE 3.9

DABS AVIONICS ACQUISITIONS
ASSUMING UG3RD SYSTEM CONFIGURATIONS 2 AND 3

	AIRCRAFT AVIONICS CLASS CLASS A		
Year	Transponders Added/Year- Commercial Fleet	Altimeters Added/Year- Commercial Fleet	DABS Avionics Added/Year- Military Fleet
1976			
1977			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985	750	74	1,991
1986	750	74	1,966
1987	750	49	1,991
1988	750	74	2,040
1989	753	128	2,012
1990	98	98	
1991	99	99	
1992	74	74	
1993	99	99	
1994	74	74	
1995	99	99	
1996	99	99	
1997	74	74	
1998	98	98	
1999	74	74	
2000	74	74	

TABLE 3.9

DABS AVIONICS ACQUISITION
ASSUMING UG3RD SYSTEM CONFIGURATIONS 2 AND 3

Year	AIRCRAFT AVIONICS CLASS CLASS B			AIRCRAFT AVIONICS CLASS CLASS C	
	Transponders Added/Year- G.A. Fleet	Altimeters Added/Year- G.A. Fleet	DABS Avionics Added/Year- Military Fleet	Transponders Added/Year	Altimeters Added/Year
1976					
1977					
1978					
1979					
1980					
1981					
1982					
1983					
1984					
1985	10,250	2,550	2,000	7,543	1,834
1986	10,280	2,580	2,000	7,567	1,860
1987	10,603	2,903	2,000	8,198	2,088
1988	10,799	3,099	2,000	8,515	2,228
1989	10,767	3,067	2,000	8,368	2,211
1990	3,364	3,364		8,991	1,647
1991	3,574	3,574		9,511	1,727
1992	3,789	3,789		10,461	1,806
1993	3,992	3,992		10,927	1,872
1994	4,257	4,257		11,477	1,926
1995	4,266	4,266		4,135	2,068
1996	4,546	4,546		4,370	2,185
1997	4,712	4,712		4,454	2,227
1998	5,126	5,126		4,834	2,417
1999	5,345	5,345		4,966	2,483
2000	5,652	5,652		5,196	2,598

TABLE 3.9

DABS AVIONICS ACQUISITIONS
ASSUMING UG3RD SYSTEM CONFIGURATIONS 2 AND 3

	AIRCRAFT AVIONICS CLASS CLASS D	
Year	Number of Transponders Added/Year	Number of Altimeters Added/Year
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985	5,281	1,980
1986	5,351	1,997
1987	5,793	2,237
1988	6,051	2,379
1989	6,010	2,339
1990	6,489	1,692
1991	6,877	1,766
1992	7,540	1,839
1993	7,914	1,898
1994	8,352	1,995
1995	4,835	2,101
1996	5,159	2,213
1997	5,378	2,243
1998	5,833	2,432
1999	6,106	2,484
2000	3,884	2,589

TABLE 3.9

DABS AVIONICS ACQUISITIONS
ASSUMING UG3RD SYSTEM CONFIGURATIONS 2 AND 3

	AIRCRAFT AVIONICS CLASS CLASS E	
Year	Number of Transponders Added/Year	Number of Altimeters Added/Year
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985	2,564	297
1986	2,571	289
1987	2,783	329
1988	2,887	347
1989	2,835	326
1990	3,055	357
1991	3,230	374
1992	3,547	389
1993	3,702	404
1994	3,886	424
1995	2,055	445
1996	2,191	469
1997	2,276	477
1998	2,472	517
1999	2,582	529
2000	1,842	553

TABLE 3.10

PERCENT OF USERS EQUIPPED WITH
DABS AVIONICS BY YEAR
ASSUMING UG3RD SYSTEM CONFIGURATION 4

Aircraft Avionics Class	Year					
	1975	1980	1985	1990	1995	2000
A	0	0	0	100	100	100
B	0	0	0	100	100	100
C	0	0	0	40	80	80
D	0	0	0	35	70	70
E	0	0	0	25	50	50
F	0	0	0	0	0	0

TABLE 3.11

PERCENT OF USERS EQUIPPED WITH
MODE C ALTIMETER
ASSUMING UG3RD SYSTEM CONFIGURATION 4

Aircraft Avionics Class	Year					
	1975	1980	1985	1990	1995	2000
A	100	100	100	100	100	100
B	100	100	100	100	100	100
C	15	30	45	60	80	80
D	15	30	45	60	70	70
E	15	15	15	25	50	50
F	0	0	0	0	0	0

TABLE 3.12

PERCENT OF USERS EQUIPPED WITH
DABS AVIONICS BY YEAR
ASSUMING UG3RD SYSTEM CONFIGURATION 5

Aircraft Avionics Class	Year					
	1975	1980	1985	1990	1995	2000
A	0	0	0	100	100	100
B	0	0	0	100	100	100
C	0	0	0	50	100	100
D	0	0	0	50	100	100
E	0	0	0	35	70	70
F	0	0	0	0	0	0

TABLE 3.13

PERCENT OF USERS EQUIPPED WITH
MODE C ALTIMETER
ASSUMING UG3RD SYSTEM CONFIGURATION 5

Aircraft Avionics Class	Year					
	1975	1980	1985	1990	1995	200
A	100	100	100	100	100	100
B	100	100	100	100	100	100
C	15	30	45	70	100	100
D	15	30	45	70	100	100
E	15	15	15	35	70	70
F	0	0	0	0	0	0

an expectation of continued Mode C implementation into the year 1985 and then an increase in implementation activity due to the availability of DABS/IPC services. The data contained in Tables 3.10 through 3.13 were used along with DABS and IPC unit cost information to estimate DABS and IPC acquisition costs assuming UG3RD Configurations 4 or 5.

Tables 3.14 and 3.15 present estimates of the number of DABS and IPC avionic sets added to the fleet by aircraft avionics category. Unit cost for avionics and total acquisition costs are described in the following section.

TABLE 3.14

DABS/IPC AVIONICS ACQUISITION
ASSUMING UG3RD SYSTEM CONFIGURATION 4

Year	AIRCRAFT AVIONICS CLASS CLASS A Transponders Added/Year-Commercial Fleet	Altimeters Added/Year-Commercial Fleet	DABS Avionics Added/Year-Military Fleet
1976			
1977			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985	750	74	1,991
1986	750	74	1,966
1987	750	49	1,991
1988	750	74	2,040
1989	753	128	2,012
1990	98	98	
1991	99	99	
1992	74	74	
1993	99	99	
1994	74	74	
1995	99	99	
1996	99	99	
1997	74	74	
1998	98	98	
1999	74	74	
2000	74	74	

TABLE 3.14 (Cont'd)

DABS/IPC AVIONICS ACQUISITION
ASSUMING UG3RD SYSTEM CONFIGURATION 4

	AIRCRAFT AVIONICS CLASS CLASS B		
Year	Transponders Added/Year-Commercial Fleet	Altimeters Added/Year-Commercial Fleet	DABS Avionics Added/Year-Military Fleet
1976			
1977			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985	10,250	2,550	2,000
1986	10,280	2,580	2,000
1987	10,603	2,903	2,000
1988	10,799	3,099	2,000
1989	10,767	3,067	2,000
1990	3,364	3,364	
1991	3,574	3,574	
1992	3,789	3,789	
1993	3,992	3,992	
1994	4,257	4,257	
1995	4,266	4,266	
1996	4,546	4,546	
1997	4,712	4,712	
1998	5,126	5,126	
1999	5,345	5,345	
2000	5,652	5,652	

TABLE 3.14 (Cont'd)

DABS/IPC AVIONICS ACQUISITION
ASSUMING UG3RD SYSTEM CONFIGURATION 4
(Millions 1975 Dollars)

	AIRCRAFT AVIONICS CLASS CLASS C	
Year	Transponders Added/Year	Altimeters Added/Year
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985	5,879	3,067
1986	5,879	3,200
1987	5,879	3,555
1988	5,879	3,828
1989	5,883	3,922
1990	8,768	5,048
1991	8,768	5,419
1992	8,768	5,811
1993	8,768	6,201
1994	8,771	6,665
1995	8,641	3,308
1996	3,641	3,496
1997	3,641	3,564
1998	3,641	3,867
1999	3,644	3,973
2000	4,156	4,156

TABLE 3.14 (Cont'd)

DABS/IPC AVIONICS ACQUISITION
ASSUMING UG3RD SYSTEM CONFIGURATION 4
(Millions 1975 Dollars)

	AIRCRAFT AVIONICS CLASS CLASS D	
Year	Transponders Added/Year	Altimeters Added/Year
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985	4,925	3,391
1986	5,311	3,514
1987	5,777	3,889
1988	6,262	4,168
1989	6,649	4,238
1990	7,205	3,751
1991	7,752	3,981
1992	8,329	4,219
1993	8,918	4,445
1994	9,585	4,734
1995	2,941	2,941
1996	3,099	3,099
1997	3,139	3,139
1998	3,405	3,405
1999	3,479	3,479
2000	3,624	3,624

TABLE 3.14 (Cont'd)

DABS/IPC AVIONICS ACQUISITION
ASSUMING UG3RD SYSTEM CONFIGURATION 4
(Millions 1975 Dollars)

	AIRCRAFT AVIONICS CLASS CLASS E	
Year	Transponders Added/Year	Altimeters Added/Year
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985	2,372	1,246
1986	2,564	1,315
1987	2,797	1,448
1988	3,039	1,562
1989	3,237	1,621
1990	3,516	3,516
1991	3,792	3,792
1992	4,085	4,085
1993	4,385	4,385
1994	4,725	4,725
1995	1,483	1,483
1996	1,564	1,564
1997	1,589	1,888
1998	1,724	1,724
1999	1,760	1,764
2000	1,842	1,842

TABLE 3.15

DABS/IPC AVIONICS ACQUISITION AND COST
ASSUMING UG3RD SYSTEM CONFIGURATION 5

	AIRCRAFT AVIONICS CLASS CLASS A		
Year	Transponders Added/Year- Commercial Fleet	Altimeters Added/Year- Commercial Fleet	DABS Avionics Added/Year- Military Fleet
1976			
1977			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985	750	74	1,991
1986	750	74	1,966
1987	750	49	1,991
1988	750	74	2,040
1989	753	128	2,012
1990	98	98	
1991	99	99	
1992	74	74	
1993	99	99	
1994	74	74	
1995	99	99	
1996	99	99	
1997	74	74	
1998	98	98	
1999	74	74	
2000	74	74	

TABLE 3.15

DABS/IPC AVIONICS ACQUISITION AND COST
ASSUMING UG3RD SYSTEM CONFIGURATION 5

	AIRCRAFT AVIONICS CLASS CLASS B		
Year	Transponders Added/Year-Commercial Fleet	Altimeters Added/Year-Commercial Fleet	DABS Avionics Added/Year-Military Fleet
1976			
1977			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985	10,250	2,550	2,000
1986	10,280	2,580	2,000
1987	10,603	2,903	2,000
1988	10,799	3,099	2,000
1989	10,767	2,067	2,000
1990	3,364	3,364	
1991	3,574	3,574	
1992	3,789	3,789	
1993	3,992	3,992	
1994	4,257	4,257	
1995	4,266	4,266	
1996	4,546	4,546	
1997	4,712	4,712	
1998	5,126	5,126	
1999	5,345	5,345	
2000	5,652	5,652	

TABLE 3.15

DABS/IPC AVIONICS ACQUISITION AND COST ASSUMING UG3RD SYSTEM CONFIGURATION 5 (Millions 1975 Dollars)

	AIRCRAFT AVIONICS CLASS CLASS C	
Year	Transponders Added/Year	Altimeters Added/Year
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985	6,165	2,947
1986	6,695	5,891
1987	7,333	5,021
1988	8,001	5,429
1989	8,554	5,633
1990	9,326	6,912
1991	10,096	7,439
1992	10,914	7,993
1993	11,757	8,553
1994	12,712	9,208
1995	4,135	4,135
1996	4,370	4,370
1997	4,454	4,454
1998	4,834	4,834
1999	4,966	4,966
2000	5,196	5,162

TABLE 3.15

DABS/IPC AVIONICS ACQUISITION AND COST
ASSUMING UG3RD SYSTEM CONFIGURATION 5
(Millions 1975 Dollars)

AIRCRAFT AVIONICS CLASS CLASS D		
Year	Transponders Added/Year	Altimeters Added/Year
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985	7,036	4,708
1986	7,587	5,031
1987	8,254	5,540
1988	8,945	5,957
1989	9,499	6,138
1990	10,293	7,534
1991	11,075	8,057
1992	11,898	8,611
1993	12,739	9,161
1994	13,693	9,812
1995	4,202	4,202
1996	4,427	4,427
1997	4,485	4,485
1998	4,864	4,869
1999	4,969	4,969
2000	5,178	5,178

TABLE 3.15

DABS/IPC AVIONICS ACQUISITION AND COST ASSUMING UG3RD SYSTEM CONFIGURATION 5 (Millions 1975 Dollars)

	AIRCRAFT AVIONICS CLASS CLASS E	
Year	Transponders Added/Year	Altimeters Added/Year
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985	3,320	2,195
1986	3,590	2,340
1987	3,916	2,567
1988	4,255	2,788
1989	4,531	2,915
1990	4,923	4,923
1991	5,310	5,309
1992	5,545	10,545
1993	6,313	6,314
1994	6,615	6,615
1995	2,076	2,076
1996	2,190	2,190
1997	2,224	2,224
1998	2,413	2,413
1999	2,470	2,470
2000	2,579	2,579

TABLE 3.16

UNIT FACILITY AND EQUIPMENT COSTS FOR DABS-ONLY SITE IMPLEMENTATION

Class 1 - DABS Sensor Only at Existing Site		
Electronics and Installed		$350,000
Provisions and Spares		90,000
Site Preparation Expenses		110,000
	TOTAL -	$550,000
Class 2 - DABS Sensor Only at New Site		
Electronics and Installation		$350,000
Provisions and Spares		90,000
Site Preparation and Building Expenses		300,000
	TOTAL -	$740,000
Class 3 - DABS Sensor Only Modular Expansion		
Required for Major Hubs		$250,000
Electronics and Installation		
Provisions and Spares		70,000
	TOTAL -	$320,000

TABLE 3.17

PROJECTED PERCENT OF GENERAL AVIATION FLEET EQUIPMENT IN THE YEAR 2000 WITH VARIOUS TYPES OF DABS/IPC EQUIPMENT UNDER TWO ALTERNATIVE SCENARIOS

Quality Scenario / Type of Equipment	High Percent Airline Quality	Preponderance of Standard and Medium Quality
High Quality (Dual)	20%	4%
High Quality Simplex	-0-	6%
Medium Quality	25%	25%
Standard Quality	40%	50%
No Equipment	15%	15%
Total Fleet	100%	100%

3.2.2 System Costs

DABS costs are based on estimates made in connection with a recent DABS acquisition paper [13]. These estimates are under review and may change depending on the results of the present E&D program and future implementation decisions. Unit costs of FAA facilities and equipment for a DABS-only site are presented in Table 3.16. Three classes of DABS sensor deployment are anticipated. In addition to the costs shown in Table 3.16, operation and maintenance costs for a DABS-only site have been estimated at $45,000 per year.

As indicated earlier, two different assumptions can be made regarding the quality of DABS-IPC avionics purchased by users. One assumption presumes a significant fraction of general aviation aircraft that equip with DABS/IPC avionics will purchase airline quality equipment. Alternatively, it may be assumed that most general aviation aircraft will equip with only standard or possibly medium quality equipment. Table 3.17 summarizes the assumed quality of equipment purchased by the general aviation fleet under each scenario. Each of these scenario is discussed separately below. Further details are also provided below on the unit cost of equipment and the total avionics acquisition costs for each scenario.

High Proportion of Airline Quality Equipment Scenario

Under this scenario, the additional airspace congestion associated with expansion of the general aviation fleet from 160,000 aircraft in 1975 to 489,000 aircraft in 2000 is assumed to result in a general upgrading of avionics requirements and capabilities as described in Chapter 1 and summarized in Tables 2.3 and 2.4. Much of this upgrading will occur in equipment carried by larger general aviation aircraft--turbine and multi-engine planes. The following discussion describes the estimation of DABS/IPC unit costs and the application of these costs to the units purchased during the period 1975-2000, assuming a requirement for a substantial number of airline quality DABS/IPC units.

Cost associated with each user's DABS and IPC equipment were estimated by ARINC Research Corporation [19]. Estimates were prepared assuming that the avionics packages were produced from discrete components and, alternatively that the avionics were produced using large scale integration of components (LSI). Both of these cost estimates are presented in Tables 3.18 and 3.19 for purposes of comparison, but only the LSI unit costs will be used to determine total user avionics expenditures for the various UG3RD configurations.

Cost categories included in the ARINC analysis, and used here, include acquisition costs, installation costs, and distribution costs. Acquisition refers to the actual purchase price of the particular piece of equipment. Distribution costs are those anticipated in a competitive market and, although normally included in acquisition costs, they are shown separately here. Installation costs refer to the anticipated cost of installation and check-out on each aircraft. Annual operations and maintenance costs are estimated at 10 percent of the initial purchase price and start the year after acquisition.

Commercial users are expected to equip with a single antenna and dual DABS transponder, and IPC equipment as appropriate to the configuration under study. Table 3.20 presents a detailed breakdown of commercial aviation IPC display equipment. These costs are included in the transponder costs shown in Tables 3.18 and 3.19.

The military is expected to deploy the minimum required equipment consistent with the level of performance and system compatibility they hope to achieve. Only a single equipment configuration was anticipated for military aircraft and will supplement already installed ATCRBS equipment. The acquisition costs shown in Tables 3.18 and 3.19 reflect only the costs of the modification package and single display and control unit equipment. Dual IPC indicators were assumed for Configurations 4 and 5. The costs for this equipment are given in Table 3.21 and military IPC equipment is assumed identical to general aviation IPC equipment. The total military avionics package, thus, consists of a single DABS modification, a single control unit, dual IPC display equipment as appropriate, and no new antenna.

General aviation aircraft avionics are classified according to the expected performance of the aircraft. High performance general aviation (Class C) were expected to install a single DABS transponder, a single control unit, a new antenna, and as appropriate, IPC display equipment. Low performance

TABLE 3.18

UNIT COSTS OF DABS AVIONICS

Aircraft Avionics Category	Cost Category	Discrete Version Cost	LSI Version Cost
Class A and B - Commercial and General Aviation	Acquisition	$13,451	$10,815
	Installation	6,092	6,092
	Total	19,543	16,907
Class A and B - Military	Acquisition	2,776	1,457
	Installation	2,633	2,633
	Total	5,409	4,090
Class C	Acquisition	6,757	5,437
	Installation	1,623	1,623
	Distribution	2,483	1,778
	Total	10,865	8,840
Class D and E	Acquisition	762	515
	Installation	157	91
	Distribution	286	193
	Total	1,205	799

TABLE 3.19

UNIT COSTS OF DABS/IPC AVIONICS

Aircraft Avionics Category	Cost Category	Discrete Version Cost	LSI Version Cost
Class A and B - Commercial and General Aviation	Acquisition	$17,649	$12,947
	Installation	6,323	6,323
	Total	23,972	19,270
Class A and B - Military	Acquisition	6,974	3,589
	Installation	2,864	2,864
	Total	9,838	6,453
Class C	Acquisition	8,856	6,505
	Installation	1,854	1,854
	Distribution	2,483	1,778
	Total	13,195	10,137
Class D and E	Acquisition	999	616
	Installation	157	91
	Distribution	599	370
	Total	1,755	1,077

TABLE 3.20

UNIT IPC DISPLAY COSTS--COMMERCIAL AVIATION

Cost Stem	Discrete Version	LSI Version
Material	$ 636	$ 305
Material Handling at 25%	159	76
Labor at $11.00/Hour	171	96
Burden at 135% of Labor	231	129
Inspection at 5% Labor & Burden	20	11
Subtotal	1,217	618
Engineering & Quality Control at 25%	304	154
Factory Cost	1,521	772
General & Administrative at 20%	304	154
Total Direct Cost	1,825	927
Profit at 15%	238	139
Selling Price	2,099	1,066
Installation (Difference)	231	231
Unit Cost	2,330	1,297

TABLE 3.21

UNIT IPC DISPLAY COSTS--GENERAL AVIATION

Cost Stem	Cost
Material	$ 260
Labor at $2.75/Hour	42
Direct Cost	302
Mark-Up for Overhead Burden and Profit at 67%	203
Factory Selling Price	506
Distributor Mark-Up at 100%	506
List Price	1,011

general aviation aircraft Classes D and E were expected to have a similar complement of equipment without the control module. Additionally, for low performance general aviation aircraft, the costs presented in Tables 3.18 and 3.19 do not reflect the costs for additional antennas. A single, $100-per-aircraft cost was used in this study as a value for new installations for antenna cost and installation. Additionally, it was assumed that the low performance general aviation equipment would have a built-in IPC display, thus, the general aviation IPC display costs of Table 3.21 apply only to the high performance general aviation equipment.

Tables 3.22 through 3.25 present annual cost estimates of actual expenses if the air traffic control surveillance system is expanded by introduction of DABS and IPC. A separate set of estimates is provided for each UG3RD system configuration which includes DABS or DABS in combination with IPC. The estimates were calculated from the implementation and acquisition data given in Tables 3.7, 3.9, 3.14, and 3.15 and from unit cost contained in Tables 3.17 through 3.19. Costs of ATCRBS improvements, taken from Table 3.6, are also included in the estimates of actual expenses anticipated in conjunction with DABS and IPC implementation.

TABLE 3.22

FUTURE COSTS OF
ATCRBS (INCLUDING EXPANSION AND IMPROVEMENTS) AND DABS
UG3RD SYSTEM CONFIGURATION 2
(Millions 1975 Dollars)

Cost Category	Engineering & Development		Facilities & Equipment			Operation & Maintenance		
Year	ATCRBS	DABS	ATCRBS	DABS	AVIONICS	ATCRBS	DABS	AVIONICS
1976	$.1	$10.0	$ .6	--	$33.4	$8.6	--	$64.8
1977	.1	8.0	7.4	--	37.4	8.6	--	68.1
1978	.1	5.0	7.4	--	38.6	9.3	--	71.9
1979	.1	1.8	7.7	--	36.8	10.1	--	75.7
1980	.1	1.5	7.7	--	37.9	10.8	--	79.4
1981	.1	1.5	7.7	--	42.9	11.6	--	83.2
1982	.1	1.5	7.7	--	53.4	12.3	--	87.5
1983	.1	1.5	7.7	--	57.5	13.1	--	92.8
1984	--	--	7.7	10.4	61.1	13.9	--	98.6
1985	--	--	7.7	14.5	286.8	14.6	.5	104.7
1986	--	--	1.0	18.8	295.6	15.4	1.1	133.8
1987	--	--	1.0	23.5	310.6	15.5	2.2	145.5
1988	--	--	1.0	12.3	320.0	15.6	3.6	157.6
1989	--	--	1.0	--	317.0	15.6	4.5	169.7
1990	--	--	1.0	--	170.6	15.7	4.5	181.8
1991	--	--	.5	--	180.7	15.8	4.5	201.5
1992	--	--	.5	--	195.8	15.9	4.5	221.2
1993	--	--	.5	--	204.4	15.9	4.5	240.9
1994	--	--	.5	--	215.5	15.9	4.5	260.6
1995	--	--	.5	--	280.6	16.0	4.5	280.3
1996	--	--	.5	--	302.0	16.0	4.5	301.8
1997	--	--	.5	--	318.4	16.1	4.5	316.5
1998	--	--	.5	--	332.8	16.2	4.5	332.2
1999	--	--	.5	--	363.3	16.2	4.5	348.3
2000	--	--	.5	--	389.9	16.2	4.5	365.8
TOTAL	$.8	$30.8	$79.3	$79.5	$4,882.9	$350.9	$61.4	$4,484.2

TABLE 3.23

FUTURE COSTS OF
ATCRBS (INCLUDING EXPANSION AND IMPROVEMENTS) AND DABS
UG3RD SYSTEM CONFIGURATION 3
(Millions 1975 Dollars)

Cost Category	Engineering & Development		Facilities & Equipment			Operation & Maintenance		
Year	ATCRBS	DABS	ATCRBS	DABS	AVIONICS	ATCRBS	DABS	AVIONICS
1976	$.1	$10.0	$.6	--	$33.4	$8.6	--	$64.8
1977	.1	8.0	7.4	--	37.4	8.6	--	68.1
1978	.1	5.0	7.4	--	38.6	9.3	--	71.9
1979	.1	1.8	7.7	--	36.8	10.1	--	75.7
1980	.1	1.5	7.7	--	37.9	10.8	--	79.4
1981	.1	1.5	7.7	--	42.8	11.6	--	83.2
1982	.1	1.5	7.7	--	53.4	12.3	--	87.5
1983	.1	1.5	7.7	--	57.5	13.1	--	92.8
1984	.1	--	7.7	15.5	61.1	13.9	--	98.6
1985	--	--	7.7	28.2	286.8	14.6	.7	104.7
1986	--	--	1.0	35.3	295.6	15.4	2.2	133.8
1987	--	--	1.0	27.5	310.6	15.5	4.5	145.5
1988	--	--	1.0	27.5	320.0	15.6	6.7	157.6
1989	--	--	1.0	29.4	317.0	15.6	9.0	169.7
1990	--	--	1.0	37.0	170.6	15.7	11.3	181.8
1991	--	--	.5	--	180.7	15.8	13.5	201.5
1992	--	--	.5	--	195.8	15.9	13.5	221.2
1993	--	--	.5	--	204.4	15.9	13.5	240.9
1994	--	--	.5	--	215.5	15.9	13.5	260.6
1995	--	--	.5	--	280.6	16.0	13.5	280.3
1996	--	--	.5	--	302.0	16.1	13.5	301.8
1997	--	--	.5	--	318.4	16.1	13.5	316.5
1998	--	--	.5	--	332.8	16.2	13.5	332.2
1999	--	--	.5	--	363.3	16.2	13.5	348.3
2000	--	--	.5	--	389.9	16.2	13.5	365.8
TOTAL	$.9	$30.8	$79.3	$200.4	$4,882.9	$351.0	$169.4	$4,484.2

TABLE 3.24

FUTURE COSTS OF
ATCRBS (INCLUDING EXPANSION AND IMPROVEMENTS) AND DABS
UG3RD SYSTEM CONFIGURATION 4

Cost Category	Engineering and Development			Facilities and Equipment				Operation and Maintenance			
Year	ATCRBS	DABS	IPC	ATCRBS	DABS	IPC	AVIONICS	ATCRBS	DABS	IPC	AVIONICS
1976	$.1	$10.0	-	$.6	-	-	$33.4	$8.6	-	-	$64.8
1977	.1	8.0	3.0	7.4	-	-	37.4	8.6	-	-	68.1
1978	.1	5.0	3.0	7.4	-	-	38.6	9.3	-	-	71.9
1979	.1	1.8	1.5	7.7	-	-	36.8	10.1	-	-	75.7
1980	.1	1.5	1.5	7.7	-	-	37.9	10.8	-	-	79.4
1981	.1	1.5	1.5	7.7	-	-	42.9	11.6	-	-	83.2
1982	.1	1.5	1.5	7.7	-	-	53.4	12.3	-	-	87.5
1983	.1	1.5	1.0	7.7	-	-	57.5	13.1	-	-	92.8
1984	.1	-	-	7.7	10.4	1.0	61.1	13.9	-	-	98.6
1985	-	-	-	7.7	14.5	1.5	329.4	14.6	.4	.2	103.7
1986	-	-	-	1.0	18.8	2.5	331.2	15.4	1.1	.5	137.6
1987	-	-	-	1.0	23.5	3.0	340.9	15.5	2.2	1.0	158.1
1988	-	-	-	1.0	12.3	2.0	347.8	15.6	3.6	1.6	178.5
1989	-	-	-	1.0	-	-	348.1	15.7	4.5	2.0	199.0
1990	-	-	-	1.0	-	-	201.6	15.7	4.5	2.0	219.4
1991	-	-	-	.5	-	-	208.8	15.8	4.5	2.0	231.3
1992	-	-	-	.5	-	-	215.6	15.9	4.5	2.0	243.3
1993	-	-	-	.5	-	-	223.4	15.9	4.5	2.0	255.2
1994	-	-	-	.5	-	-	231.8	15.9	4.5	2.0	267.7
1995	-	-	-	.5	-	-	267.7	16.0	4.5	2.0	279.1
1996	-	-	-	.5	-	-	309.2	16.0	4.5	2.0	295.4
1997	-	-	-	.5	-	-	334.0	16.1	4.5	2.0	312.6
1998	-	-	-	.5	-	-	367.4	16.2	4.5	2.0	330.1
1999	-	-	-	.5	-	-	393.7	16.2	4.5	2.0	349.1
2000	-	-	-	.5	-	-	425.5	16.2	4.5	2.0	368.5
TOTAL	$.9	$30.8	$13.0	$79.3	$79.5	$10.0	$5,275.1	$351.0	$61.3	$27.3	$4,651.1

TABLE 3.25

FUTURE COSTS OF
ATCRBS (INCLUDING EXPANSION AND IMPROVEMENTS) AND DABS
UG3RD SYSTEM CONFIGURATION 5

Cost Category	Engineering and Development			Facilities and Equipment				Operation and Maintenance			
Year	ATCRBS	DABS	IPC	ATCRBS	DABS	IPC	AVIONICS	ATCRBS	DABS	IPC	AVIONICS
1976	$.1	$10.0	-	$.6	-	-	$33.4	$8.6	-	-	$64.8
1977	.1	8.0	3.0	7.4	-	-	37.4	8.6	-	-	68.1
1978	.1	5.0	3.0	7.4	-	-	38.6	9.3	-	-	71.9
1979	.1	1.8	1.5	7.7	-	-	36.8	10.1	-	-	75.7
1980	.1	1.5	1.5	7.7	-	-	37.9	10.8	-	-	79.4
1981	.1	1.5	1.5	7.7	-	-	42.9	11.6	-	-	83.2
1982	.1	1.5	1.5	7.7	-	-	53.4	12.3	-	-	87.5
1983	.1	1.5	1.0	7.7	-	-	57.5	13.1	-	-	92.8
1984	.1	-	-	7.7	15.5	1.5	61.1	13.9	-	-	98.6
1985	-	-	-	7.7	28.2	3.5	337.1	14.6	.7	.3	104.7
1986	-	-	-	1.0	35.3	5.0	349.3	15.4	2.3	1.0	156.1
1987	-	-	-	1.0	27.5	5.0	363.9	15.5	4.5	2.0	181.7
1988	-	-	-	1.0	27.5	5.0	378.4	15.6	6.7	3.0	207.4
1989	-	-	-	1.0	29.0	5.0	384.9	15.6	9.0	4.0	233.2
1990	-	-	-	1.0	37.0	5.0	219.0	15.7	11.3	5.0	248.5
1991	-	-	-	.5	-	-	235.0	15.8	13.5	6.0	263.9
1992	-	-	-	.5	-	-	254.2	15.9	13.5	6.0	279.3
1993	-	-	-	.5	-	-	268.8	15.9	13.5	6.0	294.6
1994	-	-	-	.5	-	-	287.5	15.9	13.5	6.0	310.0
1995	-	-	-	.5	-	-	300.8	16.0	13.5	6.0	327.1
1996	-	-	-	.5	-	-	337.0	16.1	13.5	6.0	345.1
1997	-	-	-	.5	-	-	367.3	16.1	13.5	6.0	363.7
1998	-	-	-	.5	-	-	409.6	16.2	13.5	6.0	384.9
1999	-	-	-	.5	-	-	442.1	16.2	13.5	6.0	404.8
2000	-	-	-	.5	-	-	463.9	16.2	13.5	6.0	426.8
TOTAL	$.9	$30.8	$13.0	$79.3	$200.4	$30.0	$5,797.3	$351.0	$169.5	$75.3	$5,253.8

Predominant Proportion of Standard and Medium Quality Equipment

As an alternative to the assumption of an increasing quality level of avionics in general aviation aircraft, in the future it can be assumed that the majority of larger general aviation--turbine and multi-engine--aircraft will equip with only medium quality avionics. This quality of equipment scenario is described by Table 3.26. Comparison data is given in parenthesis for the 'airline quality' scenario. Unit equipment prices for this scenario, also derived from the research of ARINC Research Corporation studies [19], are given in Table 3.27. Combining the assumptions on deployment (Tables 3.9, 3.14, and 3.15), quality of equipment purchases (Table 3.27), and estimate of total DABS/IPC avionics costs given in Table 3.28.

TABLE 3.26

QUALITY OF EQUIPMENT ASSUMPTIONS--
STANDARD/MEDIUM QUALITY PURCHASE SCENARIO

	Turbine	Multi-Engine	Single Engine	Other	Year 2000 % Fleet
High Quality (Dual)	50% (100%)	5% (80%)	-	-	4% (20%)
High Quality (Simplex)	50%	20%	-	-	6% -
Medium Quality	-	50% (20%)	20% (25%)	- (100%)	25% (25%)
Standard Quality	-	25%	65%* (=45%)	-	50% (40%)
No Equipment	-	-	15%* (=20%)	100%	15% (15%)
TOTAL	100%	100%	100%	100%	100% (100%)

( ) = Airline Quality Purchases Scenario Comparison

TABLE 3.27

AVIONICS UNIT COSTS--STANDARD/MEDIUM QUALITY
PURCHASE SCENARIO

	ATCRBS	DABS	DABS/IPC
High Quality (Duplex)			
Transponder (Incl. IPC)	11,160	16,907	19,270
Mode C	6,000	6,000	6,000
TOTAL	17,160	22,907	25,270
High Quality (Simplex)			
Transponder (Incl. IPC)	7,760	8,840	10,137
Mode C	3,000	3,000	3,000
TOTAL	10,760	11,840	13,137
Medium Quality			
Transponder (Incl. IPC)	2,200	2,790	3,230
Mode C	1,680	1,680	1,680
TOTAL	3,880	4,470	4,910
Standard Quality			
Transponder (Incl. IPC)	700	899	1,177
Mode C	720	720	720
TOTAL	1,420	1,619	1,897

TABLE 3.28

ALTERNATIVE ESTIMATES OF
TOTAL DABS/IPC AVIONICS COSTS, 1976-2000
ASSUMING PREDOMINANCE OF STANDARD
AND MEDIUM QUALITY EQUIPMENT
(Millions 1975 $)

Type of Cost / Configuration No.	Equipment	Maintenance	Total
2	3,896	3,617	7,513
3	3,896	3,617	7,513
4	4,344	3,888	8,232
5	4,434	3,980	8,414

3.3 Additional Costs of DABS and IPC Implementation

The marginal costs of implementing DABS/IPC are the difference between the total cost of continuing to use ATCRBS and the total cost of implementing DABS/IPC. Estimates of marginal costs of DABS/IPC implementation are contained in Table 3.29 for each of the alternative UG3RD configurations under two sets of assumptions regarding the quality of avionics purchased. These estimates were calculated from data given in Tables Numbers 3.6, 3.22 through 3.25, and 3.28.

TABLE 3.29

MARGINAL COSTS OF DABS/IPC -- 1975-2000
(Millions 1975 $)

High Proportion Airline Avionics Quality Equipment	E & D	F & E		O & M		Total
		DABS/IPC	Avionics	DABS/IPC	Avionics	
Configuration Number						
2	30.8	79.5	1,550.9	61.4	1,094.5	2,817.1
3	30.8	200.4	1,550.9	169.4	1,094.5	3,046.0
4	43.8	89.5	1,943.1	88.6	1,262.3	3,427.3
5	43.8	230.4	2,465.3	244.8	1,865.0	4,849.3

Predominance Medium/ Standard Quality Avionics	E & D	F & E		O & M		Total
		DABS/IPC	Avionics	DABS/IPC	Avionics	
Configuration Number						
2	30.8	79.5	564.0	61.4	229.0	964.7
3	30.8	200.4	564.0	169.4	229.0	1,193.6
4	43.8	89.5	1,022.0	88.6	500.0	1,743.9
5	43.8	230.4	1,112.0	244.8	592.0	2,223.0

4.0 Upgraded Air Traffic Control Automation

Two major challenges confronting the present ATC system are the physical capacity of controllers to handle traffic and the need for increased accuracy in the metering 1/ and spacing 2/ of aircraft at terminals and enroute in order to increase the overall capacity of the system to handle traffic without increased delay. These problems, and others, are being addressed by FAA programs to increase the automation of traffic control using computer technology.

Expanded automation has been proposed for both the terminal and enroute air traffic control activities. These programs generally involve significant software development coupled with some augmentation of existing hardware by the FAA. The advance phases of automation are integrated with the use of a DABS data link and will require that controlled aircraft be equipped with a DABS transponder and IPC display (see descriptions of these programs in Chapter 3.)

For purposes of the UG3RD cost-benefit study [18] proposed automation development has been divided into (1) development necessary to provide flight data distribution and basic aircraft metering and spacing capability to the controller and (2) development of advanced metering and spacing capability, conflict resolution, and control message automation (DABS and IPC integration). Accompanying both levels of terminal and enroute automation is the provision of centralized traffic management often termed "flow control." Information on weather conditions and traffic demand at congested facilities will be analyzed by computer to determine alternate routes and facilitate decisions regarding delayed departures.

1/ Metering refers to the placement of aircraft on an airway segment or runway approach path. It involves determination of both the total number and sequence of aircraft.

2/ Spacing refers to the maintenance of minimum separation distances between aircraft.

Cost estimates were developed for the terminal, enroute and flow control elements of each of the UG3RD system configurations. Following sections of the chapter provide a systems description of existing air traffic control automation, proposed upgrading of the automation, implementation schedules, and cost estimates for terminal, enroute, and flow control elements of the UG3RD automation program.

4.1 Upgraded Terminal Automation

A basic automation system, termed the Automated Terminal Radar System (ARTS III), is now installed in sixty-two terminal radar control centers (TRACONs), one research and development center, and one training center. It consists of an alphanumeric tracking system which uses a digital computer. A display subsystem allows broadband radar data to be displayed simultaneously with alphanumeric data. ARTS III reduces the controller's visual and perceptive work load by making radar targets easier to identify. Altitude information is also presented on aircraft which have Mode C transponder equipment. Based on surveillance data, the ARTS III system generates aircraft tracks. Although ARTS III does not automate a significant portion of the controller's work load, it does provide a computerized base for higher levels of automation.

The ARTS III improvement program to date had been oriented primarily to reducing controller work load and providing a climate for future increases in productivity.

4.1.1 Proposed UG3RD Improvements

The terminal portion of Upgraded Air Traffic Control Automation focuses on improving ARTS III. Table 4.1 indicates specific improvements incorporated in the various alternative configurations evaluated by the UG3RD system cost-benefit analysis. In addition, Table 4.1 relates these improvements to two other classification schemes--one used by Metis Corporation in a recent study of ARTS III cost and benefits [20] and the other is the description commonly used by the Airway Facilities Service (AAF), FAA [2]. Data distribution and basic metering and spacing improvements assured by UG3RD Configuration 1 correspond to Phase I and part of Phase II of the Metis categories and Packages 1, 2, and part of 3 of the AAF categories.

TABLE 4.1

TERMINAL AUTOMATION IMPROVEMENTS
INCORPORATED IN UG3RD SYSTEM CONFIGURATIONS

UG3RD System Configurations	Improvements as Categorized by Metis Corp	Improvements as Categorized by Airways Facilities Services
Configuration 1 Basic Metering and Spacing Data Distribution	Phase I - All: Radar Tracking Multiprocessing Executive Fail Soft Continuous Data Recording Phase II - Part: Minimum Safe Altitude Warning Automated Flight Data Handling Basic Metering and Spacing	Package 1 - All: Radar Tracking Multiprocessing Executive Manual Fail Soft Continuous Data Recording Package 2 - All: Minimum Safe Altitude Warning Fail Soft Package 3 - Part: Flight Data Distribution Basic Metering and Spacing
Configurations 2 through 5 Advanced Metering and Spacing Conflict Resolution Control Message Automation	Phase I - All Phase II - All Including Control Message Automation	Package 1 - All Package 2 - All Package 3 - All Package 4 - All Package 5 - All Including Control Message Automation

UG3RD Configurations 2 through 5 (advanced metering and spacing, conflict resolution and control message automation) are equivalent to Metis Phase II or AAF Packages 3 through 5.

Functional features of the various terminal automation improvements may be conveniently discussed using the category detail suggested by the Airway Facilities Service. Package 1 consists of Radar Tracking, Manual Fail Soft, Continuous Data Recording, and Multi-Processing Executive. Radar Tracking permits tracking of non-beacon equipped aircraft, and correlates radar and beacon returns for greater tracking reliability. The Multi-Processing Executive is a software development which allows several input/output processors to be integrated to provide greater computer capacity. Manual Fail Soft is an equipment reconfiguration around a failed subsystem to provide continuous, but probably reduced capacity operation. Continuous Data Recording allows the ATC computer data to be continuously and automatically recorded for off-line printing.

Package 2 consists of a more advanced Fail Soft capability and software for Minimum Safe Altitude Warning.

Package 3 consists of Flight Data Distribution, Conflict Prediction, Basic Metering and Spacing, and Fail Safe. Flight Data Distribution or Automated Flight Data handling gives the ARTS III site the capability to receive data from an enroute center and automatically distribute this data in the TRACON, tower cabs and satellites. Conflict Prediction displays when violations of minimum separation standards are projected to occur. Basic Metering and Spacing will provide suggested control maneuvers to air traffic controllers so that optimum separation between arriving aircraft on a single runway can occur. The Fail Safe capability means that the ARTS III equipment will automatically reconfigure and isolate failed subsystems and therefore, permit continuous, uninterrupted operation.

Package 4 consists of Control Message Automation, Refined Metering and Spacing, Multisensor All Digital Inputs, and Associative Processor Development. Control Message Automation

will interface the ARTS with a data link for transmitting control messages to aircraft. Refined Metering and Spacing will extend the basic metering and spacing capability to departing aircraft and multiple runway situations. The Multisensor and Associative Processor Developments will upgrade some of the ARTS III equipments.

Package 5 consists of Advanced Metering and Spacing and Conflict Resolution. Advanced Metering and Spacing fully automates the systems metering and spacing capability and integrates the M&S capability with the data link. Conflict Resolution assures that aircraft separation criteria are always satisfied; generating control messages to assure separation when required.

The terminal automation improvements are oriented towards achieving benefits in the areas of runway capacity improvements, aircraft and passenger delay reductions, fuel savings, noise reduction, safety, and increased FAA controller staff savings.

The capacity improvements will occur primarily through the use of metering and spacing. The present ARTS III capability for single runway inter-arrival spacings results in an 18 second (1 sigma) accuracy. The use of basic and refined metering and spacing is expected to increase this accuracy to 11 seconds (1 sigma); and advanced metering and spacing is expected to increase threshold arrival accuracy to 8 seconds (1 sigma). The impact is greater airport capacity, reduced inflight delays, saved fuel, and a potential for reducing noise over urban areas.

Conflict Prediction and Resolution, and Fail Soft-Fail Safe System Designs, and Minimum Safe Altitude Warning Capability are expected to increase the safety of the terminal control system.

4.1.2 Implementation Assumptions

Separate implementation schedules are developed for the various alternative equipment configurations assumed by the UG3RD system cost-benefit analysis. Configuration 1 assumed that basic metering and spacing would be installed and operational by the year 1985. Configurations 2 through 5 assumed advanced metering and spacing system capability would be operational by 1990. The implementation plans described below were determined considering these assumptions, suggested implementation time schedules from the ARTS III costs and benefits study by Metis [20], and implementation time schedules suggested by Federal Aviation Administration's Airways Facilities Service [2].

Package 1 improvements are now being installed in the field and are expected to be operational in late 1976 or early 1977. F&E expenditures for these improvements are assumed to occur primarily in 1976. Package 2 improvements are expected to take place primarily in 1977 and be collaterally operational. Package 3 improvements are expected to be implemented between 1978 and 1981, with operation realization by 1984. Package 4 improvements are expected to require F&E expenditures between 1982 and 1985, with operational capability by the end of 1986. Package 5 improvements were assumed to be implemented during 1986 and 1987, and be fully operational by about 1989.

For purposes of the UG3RD system cost-benefit analysis, improvement packages were assumed to be implemented only at 30 terminals (see Table 4.2). Some of the safety-related capabilities, such as conflict prediction and resolution and minimum safe-altitude warning, may also be implemented at additional sites. These costs are not contained in estimates developed here.

4.].3 System Costs

Estimated costs of UG3RD terminal automation are presented in Tables 4.3 and 4.4. Estimating procedures and sources are described below.

TABLE 4.2

WVAS AND
TERMINAL AUTOMATION
SITES

Chicago O'Hare (ORD)
Atlanta International (ATL)
Los Angeles (LAX)
John F. Kennedy International (JFK)
San Francisco (SFO)
La Guardia (LGA)
Miami (MIA)
Washington National (DCA)
Boston (BOS)
Denver (DEN)
Pittsburg Greater (PIT)
Detroit Wayne (DTW)
Dallas Love Field (DAL)
St. Louis International (STL)
Philadelphia (PHL)
Newark (EWR)
Minneapolis Wold Chamber (MSP)
Cleveland Hopkins International (CLE)
Dallas Fort Worth 2 (DFW)
Houston International (IAH)
Honolulu (HNL)
Memphis (MEM)
Seattle Tacoma International (SEA)
Kansas City International (MCI)
New Orleans Moisant (MSY)
Tampa (TPA)
Las Vegas (LAS)
Indianapolis (IND)
Phoenix (PHX)
Covington Gr. Cinn (CVG)

TABLE 4.3

TERMINAL AUTOMATION COSTS
UG3RD SYSTEM CONFIGURATION 1
(MILLIONS 1975 DOLLARS)

Year	E&D	F&E	Maint.	Yearly Total
1976	$8.7	$29.3		$38.0
1977	2.2	2.2	.6	5.0
1978	9.4	10.0	.7	20.1
1979	7.7	10.0	.9	18.6
1980	6.7	10.0	1.1	17.8
1981		9.9	1.3	11.2
1982			1.5	1.5
1983			1.5	1.5
1984			1.5	1.5
1985			1.5	1.5
1986			1.5	1.5
1987			1.5	1.5
1988			1.5	1.5
1989			1.5	1.5
1990			1.5	1.5
1991			1.5	1.5
1992			1.5	1.5
1993			1.5	1.5
1994			1.5	1.5
1995			1.5	1.5
1996			1.5	1.5
1997			1.5	1.5
1998			1.5	1.5
2000			1.5	1.5
TOTAL	$34.7	$71.4	$33.7	$139.8

TABLE 4.4

TERMINAL AUTOMATION COSTS
UG3RD SYSTEM CONFIGURATION 2 THRU 5
(MILLIONS 1975 DOLLARS)

Year	E&D	F&E	Maint.	Yearly Total
1976	$8.7	$29.3		$38.0
1977	2.2	2.2	$.6	5.0
1978	9.4	10.0	.7	20.0
1979	7.7	10.0	.9	18.6
1980	6.7	10.0	1.1	17.8
1981		9.9	1.3	11.2
1982		4.9	1.5	6.4
1983		4.9	1.6	6.5
1984		4.9	1.7	6.6
1985		4.8	1.9	6.7
1986		12.8	2.0	14.7
1987		12.7	2.2	14.9
1988			2.5	2.5
1989			2.5	2.5
1990			2.5	2.5
1991			2.5	2.5
1992			2.5	2.5
1993			2.5	2.5
1994			2.5	2.5
1995			2.5	2.5
1996			2.5	2.5
1997			2.5	2.5
1998			2.5	2.5
1999			2.5	2.5
2000			2.5	2.5
TOTAL	$34.7	$116.4	$48.0	$199.2

4.1.3.1 Engineering and Development Costs

The engineering and development of terminal automation costs were obtained from a recent cost-benefit analysis of ARTS III improvements conducted by Metis Corp [20]. The costs are lower than those presented in the 1975 FAA ten year plan, however, the ten-year plan statistics probably include E&D activities not appropriately allocatable to the UG3RD.

4.1.3.2 Facilities and Equipment

Facilities and equipment costs for terminal automation are also based on the research conducted by Metis Corp [20] on ARTS III enhancement costs and benefits. The implementation schedule used by Metis, however, was not incorporated into present research because it conflicted with overall assumptions of the UG3RD system cost-benefit analysis. Thus, F&G costs are scheduled in a slightly different fashion from those used by Metis.

Cost estimates by package were also received from Airways Facilities [2]. These cost estimates were somewhat lower than those used by Metis:

Package 1 - $22 million
Package 2 - $ 9 million
Package 3 - $20 million
Package 4 - $10 million
Package 5 - $13 million

Package 1 and 2 costs of $31 million correlated very well with the Phase I costs presented by Metis. Packages 3 through 5, however, totaled only $43 million, well under the $84.9 million estimate for Phase II presented by Metis. In order to be conservative and consistent, with previous FAA cost-benefit documents [20], the higher costs were adopted. Differences between the Metis costs and the Airways Facilities costs may be attributable to the differences in allocations between engineering and development and facility and equipment costs of various FAA programs.

4.1.3.3 Operations and Maintenance Costs

Enhancement O&M costs developed by Metis were adopted for the UG3RD system cost-benefit analysis. An annual, steady-state cost of $2.5 million per year was estimated as the maintenance cost of UG3RD terminal automation. O&M costs

in intervening years between 1976 and the steady-state level were assumed proportional to the fraction of the total amount of F&E dollars that had been spent. No equipment replacement allowance is assumed in the maintenance estimate.

Baseline system operation and maintenance costs are not included in Tables 4.3 and 4.4. Operations costs refer to the additional or reduced number of air traffic controllers required in the upgraded system. This item is treated in a separate study on controller productivity [10]. Maintenance costs on what can be called the baseline system appeared in recent Congressional testimony by Federal Aviation Administration officials [16]. This data showed that present computer maintenance costs were $9.061 million per year and software maintenance costs were $.635 million per year. These costs could be added to those Tables 4.2 and 4.3 to obtain a total annual maintenance cost figure. Costs in the tables presently reflect only additional costs of potential automation improvements.

Neither the baseline O&M costs, nor the enhancement O&M costs include an equipment replacement allowance. Typically, this allowance would be about 15 precent of hardware F&E costs. During the course of this investigation, estimates were not made of replacement cost. A mainframe buy of computer hardware will probably be required at some future time before the year 2000. This purchase was assumed to be outside the scope of Upgraded Third Generation System improvements.

4.2 Upgraded Enroute Automation

One of the major components of the Third Generation ATC system is the computer based semi-automated enroute air traffic control system termed NAS Stage A. This system is comprised of two major subsystems--hardware and software. The hardware subsystem utilizes IBM 9020A and 9020D computers. The software system, referred to as the model A3d2 software system, has several functional capabilities including: on-line entry of proposed flight plans, automatic data exchange between ATC facilities, automatic error and legality checking, automatic flight plan preparation/revision, initiation of automatic processing on departing flights, automatic flight plan updating and data forwarding and display, automatic tracking, radar inputs processing, and automatic track and track control updating, and data forwarding and display.

4.2.1 Proposed UG3RD Improvements

Technical improvements to NAS Stage A, software model A3d2, are discussed in this section. These improvements along with estimated operational dates have been defined in recent engineering and development plans [14] and are given in Table 4.5.

Enroute improvements may be divided into two major activity phases with Phase I being further subdivided into two parts. Phase I consists of system improvements that may be made without the addition of major new hardware subsystems. Phase I enhancements are presently close to implementation in the field and engineering and development activities are advanced or nearly complete on these improvements. Phase Ia improvements likewise, require no major new subsystems, however, further engineering and development work needs to be concluded before their implementation. Phase II enhancements will require new hardware as well as long lead time engineering and development activities. Table 4.5 summarizes the enhancements by both UG3RD configuration and activity phase, and estimates the dates at which engineering and development activities and operational implementation will be completed. Individual features are discussed below.

TABLE 4.5
ENROUTE AUTOMATION IMPROVEMENTS
INCORPORATED IN UG3RD SYSTEM CONFIGURATIONS

UG3RD System Configuration	Activity Phase	Improvements	E&D Completion Date	Operational Date
	I	Computer Capacity Recovery		
Configuration 1		- Memory augmentation	1976	1980
		Conflict Alert	1976	1980
		Miminum Safe Altitude Warning	1976	1978
		Fail Soft	1976	1980
		Meterological and Aeronautical Presentation Subsystem (MAPS)	1976	1980
		Radar Situation Recording	1976	1980
	Ia	Area Navigation Interface	1980	1983
		Flight Plan Probe	1980	1983
		Computer Capacity Recovery	1980	1983
		- CCC Processing Augmentation		
		- Program Redesign		
		Conflict Resolution	1980	1983
		Local En Route Flow Control	1980	1983
		En Route Metering	1980	1983
		Control Sector Redesign and Electronic Tabular Display Subsystems (TABS)	1980	1983
	I&Ia	All	1980	1983
Configuration 2 through 5	II	Control Message Automation	1983	1988
		DABS Interface	1983	1988
		IPC Interface	1983	1988
		Computer Capacity Recovery (Advanced)	1983	1988

Computer capacity recovery consists of two major subprograms and represents an enhancement which is pursued in all activity phases. The two parts are program redesign and hardware augmentation. Hardware augmentation is meant to expand the memory size or core storage size of the 9020 computers, augment processing capability, and apply advanced state-of-the-art recovery capability techniques. Program design is concerned with determination of feasible methods of recovering computer capacity through software efficiency.

The conflict alert function aids the radar controller in predicting situations where loss of radar separation at minimum standard are about to occur. Using information presently available in the 9020 computer from the automatic tracking function and the flight plan data base, the conflict alert function provides the radar controller with a flashing alert on his display of potentially dangerous situations concerning separation standards. The alert is generated a short time before the separation minimums might actually be violated.

Miminum safe altitude warning (MSAW) capabilities will be added in the near future to the enroute system. MSAW capability is similar to that presently being implemented in the terminal control systems. It alerts the controller to situations where aircraft have come within a pre-specified altitude from the ground.

Protection against operational failure of the current automated system is provided by the capability to dynamically reconfigure the system using redundant equipment elements. This capability is referred to as "fail-safe." If additional failures occur beyond the initial level which created a fail-safe situation, a fail-soft mode is entered. Fail-soft provides planned modes of system operation which, in case of partial computer failure, result in reduced automation capabilities in some functional areas, but still provide capability to perform the prime operational mission.

The MAPS subsystem receives and integrates weather data and aeronautical information from local and national sources and distributes the necessary information to the enroute sector control positions.

The objective of radar situation recording is to provide improved ability to record and recreate events that have occurred in the enroute system. The ability to recreate such situations may be utilized for situation analysis, for operational analysis, and for determination of system performance. The recording capability would include not only voice communications but also display data.

The area navigations system is presently being expanded. Most of this capability is in enroute airspace. Automation enhancements are necessary to accommodate the new area navigation routes and operating procedures.

The objectives of the flight plan probe capability are to reduce the number of potential conflicts which have to be resolved by the radar controller, and to reduce the work load involved in coordinating, formulating and issuing IFR clearances and restrictions. The flight plan probe provides computer assistance in planning conflict-free flight plans for controlled aircraft. Flight plans are checked with one another to assure that no potential conflicts may arise. If the probe indicates a potential conflict situation, the computer will check alternatives to decrease the number of potential conflicts, and present this information to air traffic controllers.

Conflict resolution will aid the controller in resolving potential conflicts when loss of radar separation minima is about to occur. Using information from the conflict alert function that a violation may occur, the system will make use of flight plan data and tracking information to suggest potential resolutions to the controller which would not create additional conflicts. Resolution aids are likely to be in the form of heading or altitude changes or holding actions. The controller will make the final operational resolution.

The objective of local flow control is to monitor and exercise flow control over air traffic within a center so as to provide increased efficiency of ATC operations. Computer generated aids will help controllers at the local level resolve situations caused by severe weather conditions or unusual activity for demand. A predictive capability will be included. Interface with the national flow control system occurs at this level.

Enroute metering is defined as the process which dynamically regulates air traffic in sectors where aircraft are transitioning from enroute to terminal control in response to changes in terminal capacities at medium or high density terminals. The goal of enroute metering is to improve the utilization of available terminal capacities. Enroute metering capabilities would eventually interface with the terminal area metering and spacing systems. The goal is to meter the rate of arriving aircraft to correspond with the airport acceptance rate.

Control sector redesign efforts seek to achieve an integrated efficient control sector design for the input, display, and selection of flight-related control data, and for the display and selection of non-flight-related information to improve data handling efficiency to permit a reduction in sector staffing requirements thereby increasing controller productivity. This function will include the use of tabular displays and quick entry devices to eliminate the need for using flight progress strips in enroute control operations. The new capability should improve the efficiency of the sector staff.

The Phase II activities are closely related and include control message automation, and interface with the DABS and IPC systems. Control message automation will provide the capability to automatically select, process, route and format several class of messages for two way communications with aircraft via a data link. The data link capability will be required to assure continuity and manual and automatic ground-based collision avoidance commands to aircraft. IPC commands will be given on the same data link as ATC messages. This feature may reduce control costs by increasing controller productivity.

4.2.2 Implementation Assumptions

Technically feasible implementation schedules of enroute automation improvements are difficult to estimate at this stage of the engineering and development program. Near term improvement availability is reasonably certain, however, enhancements likely to enter the field beyond 1980 are difficult to estimate, both from an implementation and a cost point of view. The implementation schedule adopted for this study is contained in Table 4.5 and correlates with the terminal automation program. Similar improvements become operational at terminals and enroute at roughly the same time.

Phase I engineering and development activities are assumed to occur between 1976 and 1978; Phase I F&E expenditures, between 1976 and 1979 with a resulting operational capability in all twenty NAS Stage A sites by 1980. Phase Ia engineering and development activities span the 1979 to 1982 time period. Phase Ia implementation activities were assumed to span the 1980 to 1982 time period. Phase II engineering and development activities and implementation activities were assumed to take place during 1983, 1984 and 1985. Phase Ia operational capability is anticipated in 1983 at all sites. Phase II enhancement capabilities were assumed to become operational at all sites by 1988.

4.2.3 System Costs

This section presents cost estimates for UG3RD improvements to NAS Stage A. In general, existing FAA data were used to prepare these estimates. Main sources of information were the recent ten year plan [24] and overview document for the Upgraded Third Generation System [26]. Estimating costs for the enroute enhancements is difficult because engineering and development activities have just started and solid estimates of future implementation costs have not yet been produced. Costs presented in this report are therefore likely to change as plans and functional capabilities become more firmly established.

4.2.3.1 Engineering and Development Costs

Engineering and development costs for enroute automation improvements were taken from the FAA's ten year plan [24]. Based on the implementation schedule presented in Table 4.5, E&D costs are divided between the activity phases as follows:

Phase I	$31.1 million
Phase Ia	$44.0 million
Phase II	$33.0 million

Cost breakdowns by year are shown on Tables 4.6 and 4.7. E&D expenditures for configurations 1 through 3 were assumed to stop in 1982 because Phase II E& E would not be pursued beyond that point.

TABLE 4.6

ENROUTE AUTOMATION COSTS
UR3RD SYSTEM CONFIGURATION 1
(Millions 1975 Dollars)

Year	E&D	F&E	Maint.	Yearly Total
1976	$ 9.4	$ .8		$10.2
1977	10.7	10.0	$ .1	20.8
1978	11.0	10.0	2.1	23.1
1979	11.0	18.0	3.1	32.2
1980	11.0	20.0	6.2	37.2
1981	11.0	30.0	9.1	50.1
1982	11.0	30.0	13.5	54.5
1983			17.3	17.3
1984			15.0	15.0
1985			13.1	13.2
1986			11.7	11.6
1987			10.9	10.9
1988			10.9	10.9
1989			10.9	10.9
1990			10.9	10.9
1991			10.9	10.9
1992			10.9	10.9
1993			10.9	10.9
1994			10.9	10.9
1995			10.9	10.9
1996			10.9	10.9
1997			10.9	10.9
1998			10.9	10.9
1999			10.9	10.9
2000			10.9	10.9
TOTALS	$75.1	$118.8	$245.0	$438.9

TABLE 4.7

ENROUTE AUTOMATION COSTS
UG3RD SYSTEM CONFIGURATIONS 2 THROUGH 5
(Millions 1975 Dollars)

Year	E&D	F&E	Maint.	Yearly Total
1976	$ 9.4	$ .8		$10.2
1977	10.7	10.0	$ .1	20.8
1978	11.0	10.0	2.2	23.1
1979	11.0	18.0	3.2	32.2
1980	11.0	20.0	6.2	37.2
1981	11.0	30.0	9.1	50.1
1982	11.0	30.0	13.6	54.6
1983	11.0	30.0	17.3	58.3
1984	11.0	30.0	20.3	61.3
1985	11.0	30.0	23.1	64.1
1986			25.7	25.7
1987			23.3	23.3
1988			21.6	21.6
1989			20.5	20.5
1990			19.9	19.9
1991			19.9	19.9
1992			19.9	19.9
1993			19.9	19.9
1994			19.9	19.9
1995			19.9	19.9
1996			19.9	19.9
1997			19.9	19.9
1998			19.9	19.9
1999			19.9	19.9
2000			19.9	19.9
TOTALS	$108.1	$208.8	$404.9	$721.8

4.2.3.2 Facilities and Equipment Costs

Facilities and equipment costs for the enroute automation improvements were also taken from the FAA's ten year plan [24]. These costs were also scheduled per the implementation schedule presented in Table 4.5 as follows:

Phase I	$38.8 million
Phase Ia	$80.0 million
Phase II	$90.0 million

Due to the methodology for determining maintenance costs, it was also necessary to separately estimate the portions of F&E costs attributable to hardware and software. In Phase I, hardware costs were associated with memory augmentation and radar situation recording. Memory augmentation costs of $620,000 per site were estimated as the cost for a single 9020D storage unit. This cost is based on 1971 data on computer estimates for Air Traffic Service [3]. The 1971 price was inflated to 1975 dollars based on the cumulative change in the consumer price index over the period 1971 through 1975. For 20 NAS Stage A sites, total memory augmentation cost is estimated at $12.4 million. Radar situation recording costs were estimated from the same source at $430,000 per site, or $8.6 million for 20 NAS Stage A sites. Total Phase I hardware costs are thus $21.0 million, and this cost was assumed uniformly distributed over years 1977, 1978, and 1979.

Phase Ia hardware costs were assumed to include the addition of a CCC processor at each site at an estimated cost of $375,000 per site, or $7.5 million; and TABS displays at each site at an estimated cost of $42,000 per display. Twenty-seven displays per site or a total of 540 displays were assumed. TABS display costs are thus $22.5 million. Total Phase Ia hardware costs are estimated to be $30.0 million uniformly distributed across the four years of Phase Ia F&E expenditure period. Phase II hardware costs were assumed to be one-half the total F&E expenditure for Phase II, or $45.0 million, uniformly distributed between 1983, 1984, and 1985. Software costs were estimated as the residual difference between hardware costs and total R&E costs for each year.

4.2.3.3 Maintenance Costs

Maintenance costs are limited to maintenance personnel and exclude operating personnel. Annual hardware maintenance costs are estimated to be 15 percent of the cumulative facility and equipment expenditures for the preceding year. The 15 percent statistic was recently adopted for the Advanced Air Traffic Management System Study [34] and by Rand [28] and Mitre Corporation [34] in various costing exercises.

The Rand Corporation has estimated software maintenance costs as a decreasing percentage of F&E expenditures over a five-year period [28]. For the first five-year period after software implementation, annual O&M costs for that software declines linearly from 20 percent of F&E to 5 percent of F&E. A 5 percent level is assumed thereafter. Tables 4.6 and 4.7 summarize the maintenance costs derived according to this methodology

4.3 Central Flow Control

Major flows of air traffic are regulated at the national level from the ATC System Command Center in Washington, D.C. Central flow control operations in the center continuously compare projected traffic against the weather, airport, and navigation/control system status. Problems such as weather to be avoided or system overloads to be reduced are flagged and solutions developed in coordination with the affected enroute and terminal ATC facilities. Notices or advisories, clearance restrictions, or other similar instructions are disseminated to the appropriate facilities and other points of contact with the users.

At the present time, the Airport Information Retrieval System (AIRS I) provides data processing support for central flow control via time-share computer terminals. The first operational implementation of this system was in January 1972 and was limited to data retrieval.

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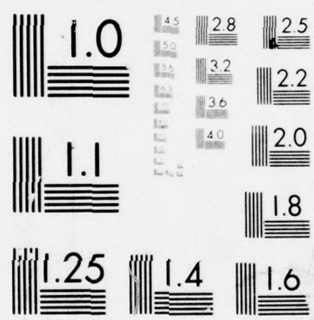

MICROCOPY RESOLUTION TEST CHART
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4.3.1 Proposed UG3RD Improvements

The next major improvement in flow control automation will be the implementation of flow control on a dedicated computer (9020A) at the Jacksonville ARTCC. The development program includes computer programs, displays, data entry devices and communication interfaces required to support central flow control operations. The primary attributes of the advanced system are:

1. More accurate demand prediction due to real time entries from NASFLO including departure reports, route modifications, departure time updates and speed modifications.

2. More efficient stacking and sequencing of aircraft due to improved traffic load predictions by selected fixed associated with the ten pacing airports.

4.3.2 Implementation Assumptions

The National Aviation System Plan, 1976 - 1985, calls for the implementation of the advanced Flow Control System on the dedicated 9020A computer to be initiated in FY 1976 with improvements continuing through FY 1985. The program will include modifications to the 9020A, additional peripheral equipment, communication interfaces, etc. The software development program will also be initiated in FY 1976.

4.3.3 System Costs

The National Aviation System Plan [24] provides the following costs:

	76	77	78	79	80	81-85	TOTAL
F&E	\$7.6M						\$7.6M
E&D	\$1.7M	2.3M	2.3M	1.0M	1.0M	5.0M	\$13.3M

These costs were adopted and are incorporated in Table 4.9. It was also assumed that the 1981 to 1985 engineering and development costs were uniformly expended at a rate of \$1.0 million per year. It was further assumed that all engineering and development costs were associated with development and implementation of software for the flow control system. Facilities and equipment costs occur only in 1976, these are

for the purchase, set-up, and check-out of the flow control system computer. Annual maintenance costs were estimated assuming that hardware maintenance expense will be 15 percent of the initial F&E. In addition, software maintenance will be a decreasing percentage of the software development cost. Software maintenance costs were assumed to decline from 20 percent of F&E in the first year after expenditure to 5 percent after 5 years and remain constant thereafter.

Table 4.8 presents the cost summary for the flow control system. Total engineering and development costs are $13.3 million; total facilities and equipment costs are $7.6 million; total maintenance cost between 1973 and the year 2000 is $46 million; for a total of $66.9 million.

TABLE 4.8

FLOW CONTROL COSTS
(Millions 1975 Dollars)

Year	E&D	F&E	Maint.	Total
1976	$1.7	$7.6		$9.3
1977	2.3		$1.5	3.8
1978	2.3		1.9	4.2
1979	1.0		2.2	3.2
1980	1.0		2.1	3.2
1981	1.0		1.9	2.9
1982	1.0		2.0	3.0
1983	1.0		2.0	3.0
1984	1.0		2.1	3.1
1985	1.0		2.1	3.1
1986			2.2	2.2
1987			2.0	2.0
1988			1.9	1.9
1989			1.8	1.9
1990			1.8	1.8
1991			1.8	1.8
1992			1.8	1.8
1993			1.8	1.8
1994			1.8	1.8
1995			1.8	1.8
1996			1.8	1.8
1997			1.8	1.8
1998			1.8	1.8
1999			1.8	1.8
2000			1.8	1.8
TOTALS	$13.3	$7.6	$46.0	$66.9

5.0 Wake Vortex Avoidance System (WVAS)

A major constraint on airport capacity is the problem of aircraft wake vortices--a pair of counter rotational air masses left in the wake of all aircraft in flight. Vortices of a large aircraft can present a severe hazard to another aircraft which inadvertently encounters the them. The following aircraft can be subject to rolling moments which exceed the aircraft roll authority and lead to dangerous loss of altitude or to a possible structural failure. The problem becomes most acute in the terminal area where a large number of aircraft operating within a small contained airspace increases the probability of an encounter with a vortex and where there is little time to recover due to the lower altitudes involved.

In the absence of an operational means to detect, track, and/or predict the location and severity of wake vortices, the FAA has maintained safety by increasing the Instrument Flight Rule (IFR) separation standards from 3 nautical miles (nmi), which was in common use prior to the introduction of the wide-bodied heavy aircraft, to at least 5 nmi for light aircraft following heavy (300,000 pounds gross take-off weight or larger) aircraft. The increase in separation standards has reduced airport arrival (and departure) capacity and poses one of the major obstacles to increasing capacity. Imposition of 5 nmi spacing during IFR conditions and practices used during Visual Flight Rule (VFR) conditions to assure safe separation have caused roughly a 10 percent loss in runway acceptance rates under IFR conditions and a 10 to 20 percent loss in the VFR rate [ ].

5.1 Proposed UG3RD Improvement

The Wake Vortex Avoidance System (WVAS) is being developed to be used in the terminal airspace to detect and/or predict the presence of aircraft wake vortices, to evaluate whether a threat exists to a following aircraft, and to command the hazard avoidance action. Premises for development of WVAS are that:

(1) Most vortices move quickly off the flight path and do not constitute a hazard to aircraft following on the same flight path even at small separations.

(2) The intensity and movement of vortices can be predicted based on a knowledge of the generating aircraft's characteristics and the existing meteorological conditions.

(3) Vortices can be detected and tracked at selected points along the approach (or departure) path through the use of sensors.

A final system configuration of the WVAS has not yet been defined. A partial model of the WVAS is being tested at Chicago's O'Hare (ORD) Airport, however, and the resultant data will be instrumental in deciding the final WVAS configuration. A configuration of WVAS incorporating all technical features now under evaluation could consist of the following components:

1. A meteorological network and computer processor capable of predicting expected vortex residual time in the approach corridor.

2. Active vortex acquisition and tracking sensors.

3. Processing equipment for coupling the predictions and active vortex sensor data to determine aircraft separation requirements.

For purposes of the UG3RD system cost-benefit analysis two levels of WVAS development have been embodied in the various alternative system configurations. Specifically, UG3RD configuration 1 assumes 'manual' WVAS capability and configurations 2 through 5 assume 'automated' WVAS capability. The basic design of the WVAS is identical for both the manual and automated WVAS. The distinction in terms of system operation is that the manual WVAS maintains separation standards with the use of a controller in the loop; the automated WVAS is interfaced with the ARTS III computer and separation standards will be established to constrain the metering and spacing demand.

5.2 Implementation Assumptions

UG3RD configuration 1 is defined to include manual WVAS capability (see Table 1.1). Given that operational WVAS technology is anticipated to be available prior to 1985 [26] and in order to maximize the performance impact of other elements of the UG3RD system, manual WVAS capability was assumed installed and operational at the 30 terminals listed in Table 4.2 by 1985. UG3RD configurations 2 through 5 are defined to include automated WVAS capability. Based on the same rationale governing configuration 1 implementation assumptions, automated WVAS was assumed installed at the 30 terminals listed in Table 4.3 by 1990. These implementation schedules differ from that suggested in a cost-benefit analysis of WVAS completed by Computer Sciences Corporation [9] which recommended that WVAS be confined to only 12 airports. Implementation assumptions of the present study are consistent with the goal of reviewing UG3RD costs

and benefits from a system perspective. WVAS implementation is required in order to maximize capacity impacts of metering and spacing capability provided by UG3RD terminal automation improvements and improved surveillance provided by DABS.

5.3 System Costs

At present, two different sensing devices are candidates for inclusion in WVAS--ground wind sensors and monostatic doppler acoustic sensors. In estimating WVAS costs for use in the UG3RD system cost-benefit analysis, it was assumed that monostatic doppler acoustic sensors would be employed. This assumption was adopted because doppler sensors are more costly than the ground wind sensors, hence including those costs in the cost-benefit analysis provides more conservative estimates of net benefits. Table 5.1 presents annual estimates of WVAS costs for various UG3RD system configurations.

5.3.1 Engineering and Development

Annual estimates of WVAS engineering costs were obtained from An Overview and Assessment of Plans and Programs for the Upgraded Third Generation Air Traffic Control System [26] for the period FY 1976 through FY 1978. A combined total was also provided for the period FY 1979 through FY 1983. In developing annual estimates, it was assumed that an equal amount would be spent on engineering and development during 1979 through 1983.

TABLE 5.1

Estimated Wake Vortex Avoidance System Costs
(Million 1975 Dollars)

	UG3RD Configuration 1			UG3RD Configurations 2-5		
Year	E&D	F&E	O&M	E&D	F&E	O&M
1976	$2.4			$2.4		
1977	4.0			4.0		
1978	3.5	$4.2		3.5	$4.2	
1979	2.4	3.6	$.2	2.4	3.6	$.2
1980	2.4	4.4	.5	2.4	4.4	.5
1981	2.4	3.7	.7	2.4	3.7	.7
1982	2.4	3.8	.9	2.4	3.8	.9
1983	2.4	4.1	1.1	2.4	4.1	1.1
1984			1.3			1.3
1985			1.4			1.4
1986			1.3		.2	1.3
1987			1.4		.2	1.4
1988			1.3		.2	1.3
1989			1.4		.3	1.4
1990			1.3		.3	1.3
1991			1.4			1.4
1992			1.3			1.3
1993			1.4			1.4
1994			1.3			1.3
1995			1.4			1.4
1996			1.3			1.3
1997			1.4			1.4
1998			1.3			1.3
1999			1.4			1.4
2000			1.3			1.3
Total	$21.9	$23.8	$26.3	$21.9	$25.0	$26.3

5.3.2 Facilities and Equipment

WVAS costs at John F. Kennedy International Airport, San Francisco International Airport, and Chicago O'Hare International Airport were taken from the Wake Vortex Avoidance System Cost/Benefit Study [9]. Cost methods employed in this source were used to calculate separate estimates of facility and equipment costs at nine other terminals:

1. Los Angeles International (LAX)
2. Dallas-Ft Worth (DFW)
3. La Guardia (LGA)
4. Denver (DEN)
5. Miami International (MIA)
6. Philadelphia (PHL)
7. Logan Field, Boston (BOS)
8. Atlanta (ATL)
9. Pittsburgh (PIT)

These estimates are given in Table 5.2. In preparing the estimates, it was not possible to conduct physical inspections of terrain to determine placement of meteorological towers. Instead estimates were based on airport layout and conform to the regulations of FAR 77 on the placement of objects within the airport vicinity. It was assumed that every runway end would be instrumented with monostatic doppler acoustic sensors. The amount of cabling required for each airport was determined by relating airport size relative to the three airports analyzed in the Wake Vortex Avoidance System Cost/Benefit Study [9].

For the remaining 18 airports where WVAS is assumed implemented, a uniform facility and equipment cost of $700,000 per terminal was assumed. This cost is compatible with the estimate for Pittsburgh (PIT), the lowest cost estimate of the 12 separate terminal estimates. Most of the 18 remaining airports are smaller than the 12 airports estimated separately and it therefore appears reasonable to assume that $700,000 per terminal is an upper bound for the 18 remaining terminals.

WVAS facility and equipment costs consist of the non-recurring cost categories used in the WVAS cost-benefit analysis [9].

TABLE 5.2

ESTIMATED WVAS
COSTS BY TERMINAL-
UG3RD SYSTEM CONFIGURATION 1

Airport	F&E Cost	O&M Cost
Chicago (ORD)	$1,085,349	$49,571
Atlanta (ATL)	1,047,980	48,169
New York (JFK)	974,581	48,475
Los Angeles (LAX)	1,464,870	42,764
Dallas (DFW)	1,036,280	48,165
San Francisco (SFO)	1,268,718	50,203
New York (LFA)	887,718	46,912
Denver (DEN)	724,240	45,601
Miami (MIA)	1,020,234	48,103
Philadelphia (PHL)	724,240	45,601
Boston (BOS)	1,307,679	41,147
Pittsburgh (PIT)	703,010	45,591

Non-recurring costs include acquisition, installation and initial training costs occurring on a one-time basis at the time of implementation. Acquisition costs include the cost of the hardware components, initial spares and repair parts, and test and maintenance equipment. Hardware components costs were taken from Table 5.3 and multiplied by the number of units required at each site. Initial spares and repair parts were estimated at 10 percent of hardware cost. Test and maintenance equipment was estimated at 3 percent of hardware costs.

Installation costs include cable laying, component emplacement, hardwiring, initial alignment, and a constant fee. Cable laying costs vary from airport to airport because of construction codes and include entrenching and cable laying (in conduct) to tie meteorological equipment to the control tower. Cable is also necessary to link the ground wind sensor lines. Costs to lay cable vary from $3.75 to 6.00 per foot. Component emplacement, hardwiring and initial alignment are estimated $15,000 for each WVAS. A $10,000 consultant fee is added for a local contractor to satisfy initial administration requirements (identifying installation specifications toward required codes) and to monitor the installation process. An initial training fee is estimated at $1250 to include the cost of training personnel to monitor the system.

Cost differentiation between manual WVAS, UG3RD system configuration 1, and automated WVAS, configuration 2 through 5, is the addition of two modems to the automated WVAS. These modems will structure the signals from the WVAS to interface with the ARTS III computer. The modems costs are approximated at $20,000 per unit.

5.3.3 Operations and Maintenance

The operation and maintenance cost consists of maintenance, repair parts, leasing, power and retraining costs. It is envisioned that the system will be maintained by in-house personnel augmented by one additional repairman. For costing purposes, an additional man-year at $18,500 plus administrative overhead at $18,500 per year, has been added to the annual recurring cost to cover the added maintenance requirement. Repair parts are estimated at 1 percent of hardware component costs. Leasing costs includes the cost to lease land for deployment of hardware at those sites where land is not available inside airport boundaries. Other leasing costs consist of leasing existing or planned cable

TABLE 5.3

WVAS HARDWARE COMPONENT COSTS

Subsystems	Unit Cost
Meteorological Subsystem:	
towers and safety features	$1,000
met sensors (solid-state)	2,000
converter multiplexer	450
line transmitters/receivers	1,000
transformers	100
tower cabling	0.50/ft.
tie-in cabling	3.75-6.00/ft.
Sensor Subsystem	
ground wind sensor (solid-state)	$2,000
converter multiplexer	450
line transmitters/receivers	1,000
sensor cabling	6,400/sensor line
tie-in cabling	3.75-6.00/ft.
monostatic Doppler acoustic system	80,000
Processing Subsystem	
Minicomputer (Nova 800)	$15,000
Software alignment	50,000
Display Subsystem	
controller display	$ 1,000
alarm system	500

from components tie-in points to the control tower from local telephone service organizations. Power (32.00kwh) is estimated at $1,500 per system per year. Retraining at an assumed 10 percent annual turnover is estimated at $1,250 per year.

Annual O&M for twelve airports are given in Table 5.2. The costs of Chicago O'Hare (ORD). New York (JFK) and San Francisco (SFO) are taken from the Computer Science Corporation cost-benefit study [9]. The other nine airport costs are values calculated for the present report. Operations and maintenance costs for the 18 terminals (where WVAS is assumed to be implemented but excluded from Table 5.2) were set at $45,000 per terminal--a value consistent with the facility and equipment estimate of $700,000.

6.0 Benefit-Related Unit Cost Estimates

A consistent set of benefit related unit cost factors was required for the UG3RD system cost-benefit analysis [18]. To this end, 1975 costs were estimated for operation of generic aircraft types, the value of air traveler time, delay costs by aircraft type, and safety-related items. Unit costs are used to establish the total value of delay reductions associated with alternative UG3RD system configurations and various safety benefits.

6.1 Aircraft Operating Costs

At the inception of this study, the most current unit cost data available for transport aircraft (air carriers and air taxi) operated by certificated route air carriers were for the year 1974 and appeared in the Aircraft Operating Cost and Performance Report, Civil Aeronautics Board [8]. The data in this publication were compiled from information reported monthly and/or quarterly by the certificated air carriers on their direct operating costs (DOC). These data are then averaged over the reporting period, in this case, FY 1974, by the CAB. The DOC is given in many forms, such as cost per aircraft mile, cost per revenue passenger mile, cost per available seat mile, and the most useful for present purpose--the cost per block hour. Block time is defined as the time from the moment the aircraft first moves under its own power for purposes of flight until it comes to rest at the next point of landing. It includes taxi time before take-off and after landing, take-off and landing time, and airborne time.

Comparable cost data are not maintained by the Civil Aeronautics Board for general aviation (GA). However, a recent study [15] conducted for the FAA Office of Aviation Policy does provide detailed GA operating costs for eight aircraft types. Because five of the GA categories represent variations of turbine-powered aircraft which, in total, constitute only 2 percent of the fleet, all turbine aircraft were combined into a single category. GA unit costs of aircraft operation were, therefore, computed for the following categories of aircraft:

Single engine, 1-3 passengers
Single engine, 4 or more passengers
Multi-engine, piston
Turbine

TABLE 6.1

ESTIMATED 1975 AIRCRAFT DIRECT OPERATING COSTS

Aircraft Type	DOC-Less Fuel ($/min.)	Fuel Consump. Rate (gal./min.)	Fuel Cost gal.($/min.)	Total ($/min.)
Air Carrier				
4 Engine				
Wide Body	$27.99	56.3	$15.37	$43.36
Conventional	12.77	29.1	7.95	20.71
3 Engine				
Wide Body	22.05	37.7	10.30	32.34
Conventional	10.35	21.7	5.92	16.27
2 Engine	8.55	15.0	4.10	12.66
Turboprop	14.46	10.6	2.90	17.36
Air Taxi	4.95	2.32	.63	5.59
General Aviation				
Single Engine, 1-3 pax	.69	.17	.13	.82
Single Engine, 4+ pax	.98	.22	.16	1.15
Multi Engine	2.49	.55	.43	2.92
Turbine	10.39	5.25	3.89	14.29

Data on 1974 operating costs for air carriers and taxis were used to estimate 1975 operating costs. This was accomplished by substituting data on 1975 fuel costs published in Aviation Daily [6] for 1974 fuel costs and then inflating remaining cost elements from 1974 to 1975 dollars by means of the consumer price index reported in Monthly Summary of Business Conditions [31]. Table 6.1 presents estimates of 1975 direct operating and fuel costs for various aircraft categories. Following CAB precedent, depreciation costs are included in the direct operating costs.

6.2 Passenger Delay Costs

In a Civil Aeronautics Board study of fare elasticities, Brown and Watkins estimated the value of time of first class air passengers at $11.97 an hour and for coach passengers at $8.09 an hour. In 1975 dollars, these estimates become $17.09 and $11.55 respectively. Based on a 1967 survey [11] of air travelers, De Vany [12] developed an estimate of passenger time which translates to $12.80 per hour in 1975 dollars. In the conduct of the ATTMS study, Rand [ ] incorporated an estimate of $13.88 equivalent 1975 dollars for the value of time for GA activities. An estimate of $12.50 per hour was adopted as the value of passenger time for use in the present study. This value was selected as consistent with existing FAA policy on the value of passenger time and is basically compatible with De Vany's estimate.

The average number of passengers per flight for various aircraft types was obtained from CAB statistics [8]. An estimate of the average number of passengers on board general aviation was provided by the Forecast Branch, Policy Formulation Division, Office of Aviation Policy, FAA. Using this information in conjunction with the value of passenger time, passenger delay cost per minute by type of aircraft was calculated and appears in Table 6.2. Also, Table 6.2 adds passenger delay cost and aircraft operating cost to estimate total delay costs per minute by type of aircraft.

TABLE 6.2

PASSENGER DELAY AND TOTAL AIRCRAFT DELAY COSTS

Air Carrier	Avg. No. Pax.	Pax. Cost ($/Min.)	DOC ($/Min.)	Total Delay Cost ($/Min.)
4 Engine				
Wide Body	166.5	34.69	43.36	78.05
Conventional	77.0	16.04	20.71	36.75
3 Engine				
Wide Body	110.7	23.06	32.34	55.40
Conventional	63.7	13.27	16.27	29.54
2 Engine	55.6	11.58	12.66	24.24
Turboprop	41.6	8.67	17.36	26.03
General Aviation				
Single Engine, 1-3 pax	1.4	.29	.82	1.11
Single Engine, 4+ pax	2.3	.48	1.15	1.63
Multi Engine	3.4	.71	2.92	3.63
Turbine	3.8	.79	14.29	15.08

6.3 Aircraft Accident Costs

The monetary cost of aircraft accidents includes the loss and/or damage to property and the loss and/or injury to human life.

6.2.1 Property

Because of FAA certification requirements, all aircraft of a given fleet are presumed to be equally safe. The probability of accident is thus presumed uniform throughout the fleet. The average present value of the various elements of that fleet can therefore be considered the basis for the repair or replacement of any element involved in an accident.

Data reported in the 1974 edition of the Airline Statistical Annual [5] estimates total air carrier (trunk and local jet) flight equipment value at slightly over $12.6 billion at the start of 1974. At that point in time this fleet consisted of 2091 aircraft; thus the average value per aircraft on January 1, 1974 was about $6.04 million.

This value is compatible with the estimated $6.0 million air carrier replacement value put forth in Establishment Criteria for Category I Instrument Landing System [23]. The nominal air carrier replacement value was taken as $6.0 million.

Replacement cost of GA aircraft is averaged over an extensive and diverse fleet. The nominal value of $50,000 put forth in Establishment Criteria for Category I Instrument Landing System [23] is compatible with a value of $47,000 per aircraft established by Rand by averaging over the 1972 GA fleet in the conduct of an AATMS benefit study [29] and that of $47,600 for the 1974 fleet determined from an Office of Aviation Policy sponsored study of GA cost impacts [15]. A value of $50,000 was adopted for use in the UG3RD system cost-benefit system.

Air taxi replacement costs were estimated at $200,000 per aircraft in the ILS study. Given the overall consistency of estimates from that study with other sources, an estimated replacement cost of $400,000 for air taxis was adopted for analysis of UG3RD costs and benefits.

The CAB recognizes several categories of damage to aircraft--destroyed, substantial damage, minor damage, and none. The cost of a destroyed aircraft is to be taken as the replacement cost given above. Insurance experience indicated that the average repair cost of a substantially damaged aircraft is one-third of the replacement cost. Repair costs are negligible

Information on the value of third party property damage arising from aircraft accidents are quite limited and no firm cost figures have been uncovered. However, estimates were made by Rand [29] based on an earlier study by Fromm [17]. These estimates are $40,000 for air carriers and $400 for general aviation. No estimate of third party property damage is available for air taxis.

6.3.2 Human Life

Aircraft accident fatalities were valued at $300,000, the amount recommended by the FAA Office of Aviation System Plans. This cost is based on non-Warsaw payments during the period 1966-1970 projected to 1975.

Non-fatal accidents are categorized as "serious" and "minor" by the CAB. Aside from the number of accidents and injuries, very little is known about the extent of injuries, the average length of hospitalization, medical costs, loss of income, etc. Fromm [17] assumed that the average seriously injured passenger requires about six months to fully recuperate from the accident with a per injury cost of $45,000 for air carrier and air taxi accidents and $38,000 for GA accidents. The lower cost attributable to the GA victim, despite a generally higher income, reflects much lower per incident accident costs.

For minor injuries, Fromm assumed that the victim is incapacitated for one month. The per injury cost is estimated at $6000.

Costs of aircraft accidents are summarized for property damage and damage to human life in Table 6.3.

TABLE 6.3

UNIT AIRCRAFT ACCIDENT COSTS
(000's DOLLARS)

Property Damage	Destroyed	Substantially Damaged	Minor Damage or None	Third Party Damage
Air Carrier	$6,000	$200	$0	$40
Air Taxi	200	67	0	-
General Aviation	50	16	0	0.4

Loss or Injury to Human Life	Fatality	Serious Injury	Minor Injury
Air Carrier	300	45	6
Air Taxi	300	45	6
General Aviation	300	38	6

BIBLIOGRAPHY

1. Administrative Sciences Corporation, Econometric Estimates of Air Traffic Control and other Parameters for Evaluating the UG3RD ATC System (Draft). Prepared for the Federal Aviation Administration, Department of Transportation, Washington, D.C., February 1976.

2. Airway Facilities Service, Federal Aviation Administration "Communication Concerning Terminal Automation."

3. Airway Facilities Service, Federal Aviation Administration "Communication on Automation Costs"

4. Aviation Daily, "Aircraft Fuel Cost Per Gallon, Year Ended June 30, 1973 and July 1973 Through August 1974." September 30, 1974.

5. Aviation Daily. Airline Statistical Annual. 1974.

6. Aviation Daily. "Domestic Fuel Consumption and Cost." August 11, 1975.

7. Brown, S. and Watkins, W. Measuring Elasticities of Air Travel from New Cross Sectional Data. Civil Aeronautics Board. August 1971.

8. Civil Aeronautics Board. Aircraft Operating Cost and Performance Report FY 1974. Washington, D.C., February 1975.

9. Computer Sciences Corportation, Final Report for the Wake Vortex Avoidance Cost Benefit Study (Draft). Prepared for the Federal Aviation Administration, Washington, D.C., March 1975.

10. Couluris, G. T. and Johnson, J. M. First-Cut Comparative Cost Estimates of Productivity of UG3RD ATC Alternatives. Draft Report, Stanford Research Institute, Menlo Park, California, December 1975.

11. Department of Commerce. 1967 Census of Transportation GPO, Washington, D.C., 1969.

12. De Vany, A, "The Revealed Value of Time in Air Travel," Review of Economics and Statistics, Volume 56, February 1974.

13. Federal Aviation Administration, Department of Transportation. Acquisition Paper for the Discrete Address Beacon System (DABS). Washington, D.C., May 30, 1975.

14. Federal Aviation Administration, Department of Transportation. Engineering and Development Program Plan-En Route Control. Report No. FAA-ED-12-2A. Washington, D.C., February 1975.

15. Federal Aviation Administration, Department of Transportation. General Aviation Cost Impact Study-Aircraft Rental Value and Cost Data 1972-1974. Washington, D.C., March 1975.

16. Federal Aviation Administration, Department of Transportation. "Testimony Before ....

17. Fromm, G., Aviation Safety, Law and Contemporary Problems, Duke University School of Law, Volume 33. November 3, 1968.

18. Fromme, William, and Rodgers, John M. Policy Analysis of the Upgraded Third Generation Air Traffic Control System. Federal Aviation Administration, Department of Transportation, Washington, D.C., forthcoming 1976.

19. Kowalski, Stanley; Haspert, J. Kent, and Witt, James. Cost Analysis of the Airborne Portion of the Discrete Address Beacon System Intermittent Positive Control Concept (DABS/IPC) (Draft Final Report). ARZINC Research Corporation, Washington, D.C., August 1975.

20. METIS Corporation. ARTS III Enhancements and Benefits. Prepared for the Federal Aviation Administration, Department of Transportation, Washington, D.C., September 1975.

21. Natchipolsky/Hogan. "Communication from SRDS on Cost Estimates." 1975.

22. Office of Aviation Policy and Office of Aviation Systems Plans, Federal Aviation Administration, UG3RD Baseline and Implementation Scenario. Department of Transportation, Washington, D.C., forthcoming 1976.

23. Office of Aviation System Plans, Federal Aviation Administration. Establishment Criteria for Category I Instrument Landing System. FAA-ASP-75-1, Department of Transportation, Washington, D.C., March 1975.

24. Office of Aviation System Plans, Federal Aviation Administration. National Aviation System Plan 1976-1985. Department of Transportation, Washington, D.C., March 1975.

25. Office of the Secretary of Transportation. FAA Airport and Airway System Cost Element, Cost Allocation Study. Department of Transportation, Washington, D.C., February 1972.

26. Office of System Engineering Management, Federal Aviation Administration. An Overview and Assessment of Programs for the Development of the Upgraded Third Generation Air Traffic Control System. Department of Transportation, FAA-EM-75-5, Washington, D.C., March 1975.

27. Pozesky, Martin. "Communication from Systems Research and Development Service on the Definition of ATCRBS Improvements. 1975.

28. Rand Corporation. Cost Comparisons of Advanced Air Traffic Management Systems, Report No. R-1319-DOT. Santa Monica, California, July 1973.

29. Rand Corportation. Some User Benefits Achievable from an Advanced Air Traffic Management System, The Rand Corporation, R-1320-DOT. Santa Monica, California, July 1973.

30. Rogers, Robert A.; Drago, Vincent J., and Cheaney, Ed A., Estimation of UG3RD Relay Reduction. Federal Aviation Administration, Department of Transportation, Washington, D.C., forthcoming 1976.

31. Security Pacific Bank. Monthly Summary of Business Statistics. Los Angeles, California, July 1975.

32. Simpson, T. R.; Smith, Arthur, and Malney, J. Estimation of UG3RD Safety Benefits. Federal Aviation Administration, Washington, D.C., forthcoming 1976.

33. Smith, Arthur. Estimation of UG3RD Capacity Impacts. Federal Aviation Administration, Department of Transportation, Washington, D.C., forthcoming 1976.

34. Transportation System Center, Department of Transportation. Advanced Air Traffic Management System Study-Technical Summary, Report No. DOT-TSC-OST-75-6. Cambridge, Mass., March 1975.

35. Transportation Systems Center, Department of Transportation Cost Analyses Supporting the Cost-Benefits Study of the Upgraded Third Generation ATC System, Report No. WP-420-64-17, Cambridge, Mass., December 1975.